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ORIGINAL ARTICLES.

On the Family *Cyclidae* Packard.

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(PLATE XI.)

I. Introduction.
II. Historical.
III. Description of Specimens.
IV. Structural.
  α. Dorsal Surface.
  β. Ventral Surface with Appendages.
  γ. Eyes.
V. Affinities.
VI. Habits.
VII. Revision of Genera and Species.
VIII. Summary.

I. Introduction.

THE genus *Cyclus* contains a number of small Arthropoda which are found in the Carboniferous rocks of Europe and the United States. As a rule the fossils are small, less than an inch in diameter, and very often they are enclosed in ironstone nodules. Consequently they are generally overlooked and are rarely found in collections.

Most of the published details were made available by the researches of the late Dr. Henry Woodward, F.R.S., and it was with the intention of making further studies that Captain R. W. Palmer, M.C., M.Sc., obtained on loan all the available material from the British Museum (Natural History) and from the Manchester Museum. Following on Palmer's death, the specimens were handed to me to complete the investigations, but, owing to the slight progress which he had made, a few isolated notes and two rough pencil sketches, I began afresh and finally obtained the results given in this paper.

II. Historical.

The genotype of *Cyclus* was described by Professor J. Phillips in 1836, under the name of *Agnostus* ? *radialis*.[1] The horizon and locality were given as the Carboniferous Limestone, Bolland, Yorkshire. Six years later de Koninck established the genus

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[1] J. Phillips, *Geology of Yorkshire*, vol. ii, 1836, p. 240, pl. xxii, fig. 25.

Cyclus with *radialis* as its type species, and added *brongniartianus*.[1] In 1868 Woodward described *C. rankini*[2] from the Carboniferous Shales of Carluke, and in 1870 he figured *C. bilobatus, harknessi, jonesianus, torosus, wrightii, agnotus*, and *laxus*.[3] Of these, the first five were new species from the Carboniferous Limestone of Yorkshire and County Cork, whilst the last two had been distinguished at an earlier date by H. von Meyer, who assigned them to his new genus *Halicyne*; they came from the Muschelkalk of Rottweil. Dr. Peach described *C. testudo*[4] in 1883. Ten years afterwards Woodward gave an account of *C. scotti*[5] and Cowper Reed of *C. woodwardi*.[6] The following year Woodward made his last addition to the list with *C. johnsoni*.[7]

In the United States six forms have been described. The first was *C. americanus*[8] Packard, from the Coal Measures of Mazon Creek, Illinois; subsequently Rogers described *C. communis, limbatus, minutus, packardi*, and *permarginatus*[9] from the Iola Limestone of Coal Measure Age.

III. DESCRIPTION OF SPECIMENS.

A preliminary survey of the material available for study showed that the specimens fell into two groups, according to the way in which they were preserved. The first group was that in which the fossils were in a limestone matrix and in which the test alone had survived. The second group was that in which the matrix was either nodular ironstone or else shale. In this group fragmentary remains of appendages were fairly common, and since the majority of the specimens were referable to *johnsoni*[10] the following descriptions relate to that species.

Out of the numerous specimens which were examined (between seventy and eighty) four, together with their counterparts, contained all the structures which were detected. These four specimens are described below. It was often the case that the moulds, or counterparts, showed the detail to greater advantage than the actual fossils; for this reason most of the figures in the text represent the moulds.

In the descriptions "dorsal" and "ventral" apply to the surfaces which Peach and Woodward designated by those terms, i.e. the ventral surface, is that which is largely composed of radiating plates, and the dorsal surface is that on which the ridges and side lobes of Woodward's descriptions are situated. Similarly Woodward's determination of the anterior and posterior ends of the animals is adopted.

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[1] de Koninck, *Descr. d. Anim. Foss. Terr. Carb. d. Belge*, 1842, p. 591, pl. iii.

[2] H. Woodward, *Rept. Brit. Assoc., Norwich*, 1868, pp. 72–5, pl. iii, fig. 2.

[3] H. Woodward, GEOL. MAG., 1870, pp. 554–60, pl. xxiii.

[4] B. N. Peach, *Trans. Roy. Soc. Edin.*, vol. xxx, 1883, p. 227, pl. xxvii, figs. 9–9*d*.

[5] H. Woodward, GEOL. MAG., 1893, p. 28, 2 woodcuts.

[6] F. R. Cowper Reed, ibid., pp. 64–6, 1 woodcut.

[7] H. Woodward, GEOL. MAG., 1894, pp. 530–9, pl. xv.

[8] A. S. Packard, *American Naturalist*, vol. xix, 1885, p. 293. A. S. Packard, *Mem. Nat. Acad. Sci.*, vol. iii, 1885, Carb. Xipho. Faun. N. Amer., 2 plates.

[9] A. F. Rogers, *Kansas Univ. Sci. Bull.*, vol. i, 1902, No. 10, 1 plate.

[10] *Johnsoni* is now put in the genus *Halicyne*.

Specimen A. Reg. No. L11753A, *Mus. Manc.*

This fossil is exposed from the dorsal surface, which is broken away in places. Through the gaps the ventral test is to be seen.

The carapace is 26·5 mm. in length and 31 mm. in width. It is rounded, with a shallow V-shaped notch posteriorly; in front it is much flattened. Round the edge is a flat brim, 1 mm. across in the widest part. The margin is followed by a ridge about 0·5 mm. high. As it approaches the region of the head the ridge passes into two raised, tumid, oval prominences which are placed one on either side of the centre line and about 4 mm. distant. Their long axis is inclined to the centre line of the fossil at an angle of about 10°. These prominences are 5 mm. long, 4 mm. wide, and about 1 mm. high. At the rear of the fossil the marginal ridge turns inward towards the centre to form a median dorsal ridge 5·5 mm. long. Where the ridge has been broken away, together with other portions of the dorsal surface, it is replaced by a narrow depression of slight depth which is 5 mm. long. Thus the entire ridge was originally between 10 and 11 mm. in length. Inside the marginal ridge is a broad, shallow depression with a punctate ornamentation. The depression tapers as it approaches the head and tail of the animal. Its inner edge rises up to a nearly flat platform round whose edge is a low, narrow ridge with its summit about 1 mm. higher than that of the marginal ridge, from which its greatest distance is 5·5 mm. This inner ridge is recurved behind and passes into the median dorsal ridge. To the front it is limited by the two prominences already mentioned. There is enough remaining on the left hand side to enable its course to be traced with accuracy. On the right the anterior half has been broken off together with the greater portion of the centre of the carapace.

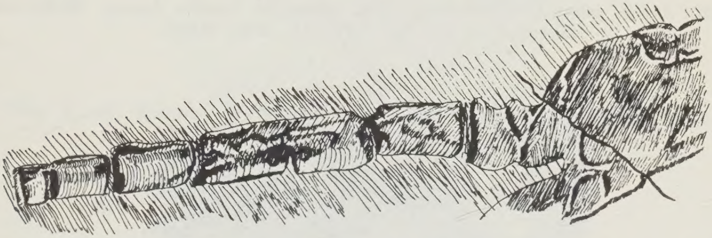

FIG. 1.—*Halicyne johnsoni* Woodward. Coal Measures, Sparth, Lancs. Base of antenna. × 5. No. L11753A, Mus. Manc.

Through the large hole in the test a portion of the ventral surface is to be seen. In the centre is a V-shaped plate bounded by grooves from which other grooves, also forming the boundaries of plates, radiate outwards. This plate is at the anterior end of what is left of the dorsal ridge. The radiating grooves limit trapeziform plates which become wider as they proceed outwards. In the specimen under consideration six of them are visible on the left and three others on the right. The dimensions of one which is complete are: the anterior side 7 mm., the side next the central plate, 1 mm., the posterior side 6·5 mm., and the outer side 2·5 mm. At the outer end are two rounded, sub-angular facets. That which is anterior is roughly pear-shaped, with its long axis in the same direction as the long axis of the trapezium; it is 2 mm. long, and just over 1 mm. wide. The hinder one is more of a lozenge shape with sides about 1·5 mm. in length. Similar plates and facets are figured below (Figs. 5, 6, 8).

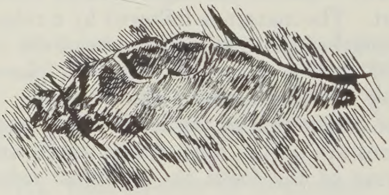

Fig. 2.—*H. johnsoni* Woodward. Coal Measures, Sparth, Lancs. Reflected labrum. × 5. No. L11753A, Mus. Manc.

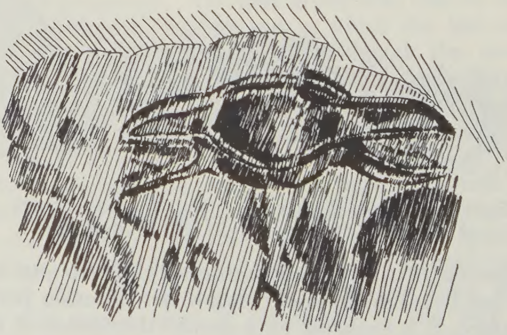

Fig. 3.—*H. johnsoni* Woodward. Coal Measures, Sparth, Lancs. Labrum and metastoma. × 5. No. L11754A, Mus. Manc.

In the region of the head some important structures are well preserved; these are the antennae and a peculiar flap. The antennae are seen in longitudinal section, and a drawing of the base of one of them is given in Fig. 1. They are borne on lateral processes arising from the side of the head. There are four basal segments, each 2·5 mm. long and 1·75 mm. in diameter. Following these is a flagellum of numerous small segments of which the first is 1·5×0·75 mm. and is about twice the size of any of those which succeed it. The total length of the longer of the antennae is 20 mm.; only a small portion of the tip appears to be lost. Since these appendages are seen in section they show up as a series of pits without any great amount of detail. Along the inner surface of the anterior margins is a confused structure having somewhat of the appearance of a thin-walled tube. On either side of the joint between the third and fourth segments in the figure are two prominent pimples. Similar pimples are found inside the antennae of other specimens.

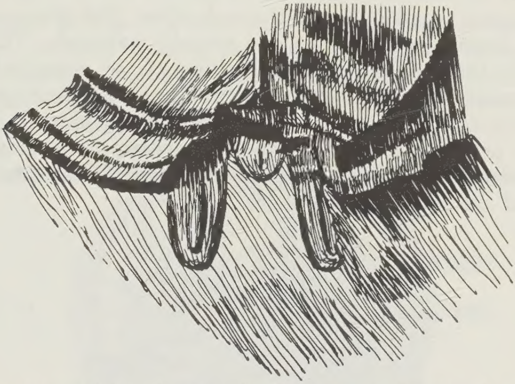

FIG. 4.—*H. johnsoni* Woodward. Coal Measures, Sparth, Lancs. Caudal fork. × 5. No. L11754A, Mus. Manc.

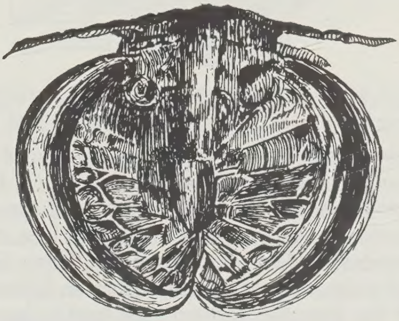

FIG. 5.—*H. johnsoni* Woodward. Coal Measures, Sparth, Lancs. Ventral surface. × 2. No. L11902A, Mus. Manc.

On the counterpart the structure shown in Fig. 2 is preserved between the antennae. It is present on the fossil, but not in such good condition. It is nearly at right angles to the dorsal surface, and has the appearance of a flap which has been reflected from a ventral position to that which it now occupies. The free border is curved, and in the centre is an oblong area which appears to owe its shape to the coalescing of two squares. The nick in the periphery seems to indicate this. In length the flap is 8·5 mm., and in extreme width 2 mm.

Specimen B. Reg. No. L11754A, *Mus. Manc.*

This specimen agrees with the former in being exposed from the dorsal aspect, and the general arrangement of the ridges and other features is the same. As a result of pressure the dorsal and ventral surfaces have been squeezed into each other, but there is no doubt that the dorsal surface is the one actually exposed. This is made certain by the freedom from distortion of the marginal portions. It is the centre which is covered by faint lines intersecting the ridges and tracing out the general characters of the underside. One new feature is prominent, namely, that the median dorsal ridge becomes forked and that each branch is double, as shown in Fig. 14. The main interest of the fossil lies elsewhere.

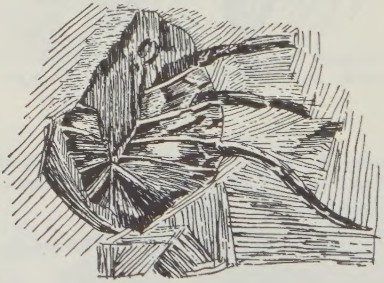

Fig. 6.—*Halicyne* sp. Coal Measures, Sparth, Lancs. Ventral surface with three rami of limbs. × 2. No. In.18598, B.M. (N.H.).

A curious structure is preserved in the head region. It is beautifully clear on the counterpart from which Fig. 3 is taken. A series of grooves and crevices defines a fusiform area which has every appearance of being a flap with the free margin directed towards the hinder end of the animal. Immediately posterior to it is a curved ridge with the central portion following the outline of the centre of the flap and the two ends turned back away from it. The flap is 8·5 mm. long, 2·5 mm. wide in the middle, and it occupies a position corresponding to that which would be taken up by the flap in specimen A if it were turned back parallel to the ventral surface. From their general positions and relationships the two flaps appear to be identical, and it is owing to the pressure to which this fossil has been subjected that the flap and ridge show through on to the dorsal surface.

The antennae are not preserved.

At the posterior end are two elliptical plates which are directed backwards, and which project beyond the margin of the carapace.

They are 3 mm. long and 1·5 mm. wide, with a broad, low ridge in the centre. Between them is a rounded projection, about 1 mm. in diameter, which bears a narrow groove, less than 0·5 mm. long, in the antero-posterior axis of the body. The plates articulate with the terminal segment of the body, of which the semicircular projection is a part. This segment is badly crushed, and is not easy to make out. It seems to have been slightly broader than long.

Specimen C. Reg. No. L11902B, *Mus. Manc.*

The original of Fig. 5 is the counterpart of this specimen, which is the most valuable of all in the assistance which it gives towards forming an accurate picture of the ventral surface. In this case the whole of the centre of the dorsal shield has been broken away, leaving the underside exposed.

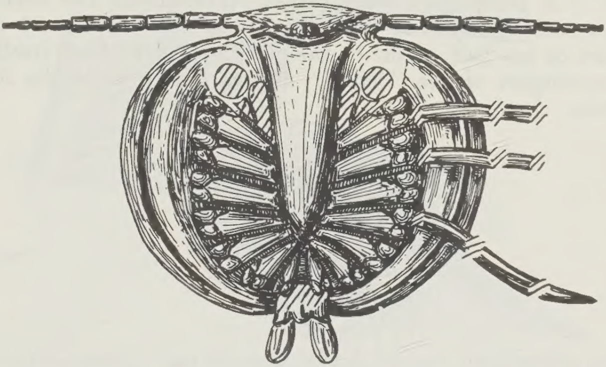

Fig. 7.—*Halicyne.* Reconstruction of details of the under side. × 2.

As was pointed out in the description of Specimen A, the ventral surface is largely made up of a great V-shaped plate with other trapeziform plates radiating from it. These vary in size. The most anterior is 5 mm. long, the third and largest 6·5 mm., and the hindmost 4·5 mm. There are seven pairs of plates in all. Each plate carries the two distal facets previously described. In several of them the pear-shape of the anterior facet is seen to be due to the presence of a small triangular plate adjacent to the facet itself (Figs. 5, 8). The centre of the fossil is occupied by a broad, low ridge which starts in the region of the head, continues backwards for a distance of 7 mm., and is 2 mm. wide. The posterior part of this ridge has been broken away and it is seen to lie over the central plate. The latter, which is exposed for some 5·5 mm., is 3 mm. wide. It tapers slightly to the fourth pair of plates, and then comes quickly to a point.

In the angles between the anterior pair of plates and the median ridge are certain ill-defined structures. Their general relations are given in Fig. 7, and their actual appearance, slightly emphasized for the sake of clarity, in Fig. 5. There are two circular bodies articulating with the curved bases of two triangular plates. These, in their turn, are external to two other plates. The last have straight edges next the trapezia and the central ridge, but their boundary is completed by a curved line. The circle is 1·5 mm. in diameter; the triangle, which is roughly isosceles, has a base of 1 mm. and an altitude of 2 mm.; the third plate has an extreme length of 4 mm.

No details are visible in the head itself, and the antennae are poorly preserved. The marginal portions of the carapace agree with those of specimen A.

The fossil is 21 mm. long and 24·5 mm. in diameter.

Specimen D. Reg. No. In.18598, *B.M.* (*N.H.*).

The great importance of this example lies in the presence of three "legs"[1] in fairly good preservation. The nodule has been split open in such a way that the "legs" and the counterpart of the fossil are on one half, whilst on the other half is the fossil itself with the counterpart of the "legs". Figure 6 represents the former specimen.

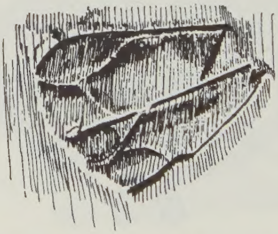

FIG. 8.—*H. johnsoni* Woodward. Coal Measures, Sparth, Lancs. Two protopodites. × 5. No. L11902A, Mus. Manc.

Three distinct trapezia remain on the right of the central plate. Comparison with specimen C shows that they are the second to fourth. Opposite the second and fourth are two "legs", the other coming in the position of the first plate. The facets are just visible, and it is seen on a careful scrutiny that the two first "legs" articulate with the *posterior* facets of the first and second plates. The other one is joined to the *anterior* facet of the fourth plate. Out of the three "legs" only the last is complete, but, since they agree in all other respects, a description of this one will suffice.

So far as can be made out, each limb consisted of three segments. The proximal segment is about 4 mm. long and 1 mm. wide; it is bowed anteriorly, and its position on the matrix is outwards and backwards. Both of the other segments follow the same general direction. The median segment is similar to the first, but tapers slightly as it proceeds outwards; it is not so curved and is about

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[1] The word "legs" is used here so as not to prejudge the question of homology which is argued in section 4β.

5 mm. long. Following it is a third, shorter segment, some 3 mm. long, which tapers to a point. In cross-section all of these segments are pear-shaped. The blunt edge is to the front and the sharp edge, which has the appearance of having been fringed with setae, to the rear. The details of the articulations cannot be made out.

In common with the three specimens previously described this fossil comes from the Middle Coal Measures of Sparth Bottoms, near Rochdale. Mr. W. Baldwin, F.G.S., informs me that the actual horizon is " 135 to 180 feet above the Royley Mine (Arley) at Rochdale ".

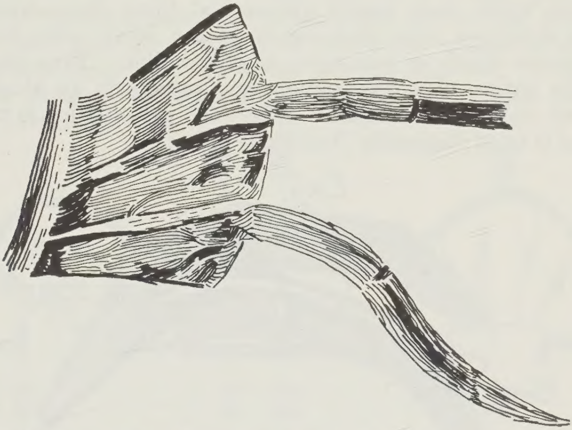

FIG. 9.—*Halicyne* sp. Coal Measures, Sparth, Lancs. Protopodites and two rami. × 4. No. In.18598, B.M. (N.H.).

IV. STRUCTURAL.

a. Dorsal Surface.

Woodward gives the following description of the dorsal surface of *H. johnsoni* : " Carapace rounded, width somewhat greater than length, broader and flatter in front, narrower behind, and with a shallow rounded indentation at the centre ; having a broad and well marked flattened rim, followed by a corresponding shallow depression around the lateral and posterior borders ; front border tumid with two . . . rounded or ovoid prominences ; carapace with a median dorsal ridge reaching rather more than half-way up the centre of the shield, then bifurcating so as to embrace a triangular space, which widens out to the anterior border [each leg of the bifurcation consists of two ridges] ; carapace, with moderately raised and roundly swelling side lobes and with a pair of smaller oblong faintly raised lobes next the median ridge." Later he says : " wherever the surface is preserved there is a fine granular [should be ' punctate '] ornamentation observable, more especially in the hollow formed within the broad flattened rim that surrounds the greater part of the shield."

There is no need to modify this. From the condition of certain specimens, it is probable that the carapace was calcified and, seemingly, it was about as thick as the shell of an average hen's egg.

β. *Ventral Surface.*

No one fossil reveals the entire ventral surface and it was found necessary to attempt a reconstruction. This is reproduced as Fig. 7. A series of measurements showed that the average proportions were as 5 : 6, and the outline of the test was drawn from the specimen which most nearly approached those dimensions. The various structures were then inserted, each being taken from that specimen in which it was most plainly visible. Thus the figure is in the nature of a compilation, and represents an ideal rather than any one particular fossil. Where the preservation is poor the drawing is ruled diagonally from right to left.

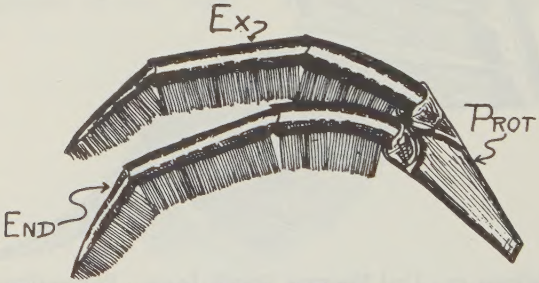

Fig. 10.—Enlarged restoration of limb of *Halicyne*; the setae are conjectural. *Prot.*, protopodite; *Ex.*, exopodite; *End.*, endopodite.

The ventral surface is an orderly mosaic of plates, and this is the chief reason for the difficulties which stand in the way of formulating a correct interpretation of the various parts. As the pressure of the overlying sediments grew greater with their increasing thickness the ventral surface was pushed up into the concavity of the carapace. In that position it was preserved. When nodules which enclose such fossils are split open the central portion of the carapace often comes away and leaves the margin in apparent organic connexion with the distal extremities of the radiating plates. To this condition Woodward gave the name *H. rankini*. Another and more serious result of the pressure is that the chief features of the dorsal and ventral aspects are commonly found in nearly inextricable confusion on the exposed surface of the fossil. By comparison with those specimens in which the dorsal surface alone is visible, the details may be placed on their appropriate surfaces.

Turning now to the diagram, and referring to it systematically, it is seen that the antennae are uniramous and borne on lateral processes arising from the side of the head. These processes may quite possibly represent a basal segment which has become fused to the head. Since there is no direct evidence of this, it is preferable to regard them as outgrowths of the head itself.

In the greater number of cases they are extended in a line at right angles to the body. Although this position makes it probable that they were used for swimming it is also certain that the antennae were sensory organs as well. This is shown by the pimples which are seen on the interior of the segments, and which, doubtless, represent pits at the bottom of which sense hairs originated.

None of the specimens shows any sign that the antennae were biramous, nor do they show any sign of a second pair. The uniramous condition seems to be in favour of the view that they are the first pair, for in many of the lower crustacea the first antennae are simple and the second pair are branched. Woodward regarded them as the second pair on account of their probable natatory function.

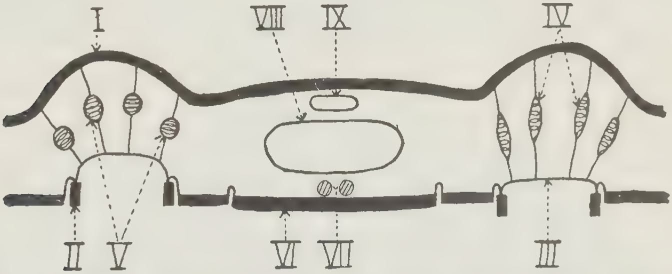

Fig. 11.—Section through suckers and dorsal prominences of *Halicyne*. Hypothetical. Enlarged. I, Dorsal prominence; II, Rim of sucker; III, Flexible floor of same; IV, Muscles relaxed; V, Muscles contracted; VI, Sternite; VII, Nerve-cords; VIII, Gut; IX, "Heart."

In the centre line between the antennae is a large transverse flap, or lappet, of roughly fusiform outline. It conceals in part a tumid arcuate ridge. This flap on the under-surface of the body covers the mouth and corresponds in position to similar structures in other Arthropoda. It may therefore be called the labrum. The impression shown in Fig. 2 is on the free margin and, when in its normal position, would coincide with the greater part of the oral opening. In all probability the shape of this impression is due to the free ends of two of the mouth-parts having been lodged there. Such mouth-parts would be the mandibles and, bearing in mind the squareness of the recess, it is fairly certain that they were of a type adapted for biting.

The ridge is immediately behind the labrum and has its convex side directed backwards. Both ends are bent backwards. From its position and relationships this ridge is evidently the metastoma.

There are seven pairs of radiating plates each of which bears distally two sub-angular facets of rounded contour. On the anterior margin and immediately adjacent to the anterior facet is a small triangular plate. These triangles *may* represent the vestiges of a second basal segment. They are not the "curious oblique scars" mentioned by Woodward,[1] "which may indicate the points of attachment of spines or setae." Certain specimens from Eskdale, Dumfries, show these markings which, to me, are in the nature of puckers, caused by the pressure which has been exerted on the shales, rather than anything of morphological significance.

Text-figures 8 and 9 enable the structures of the limbs to be made out and show the essential features on which the restoration in Fig. 10 is based. It will be seen that the anterior facet is quite distinct from the small triangular plate and that the pear-like outline so often seen in the fossils is illusory. Fig. 9 also indicates that the "legs" previously mentioned were attached to both the anterior and posterior facets. Now, since the "legs" are similar in shape, cross section, and general appearance; since the two facets correspond in all details, excepting only the triangular plate, which does not belong to the facets properly so-called; and since the "legs" have been detected in organic connexion with both the anterior and posterior facets; therefore, it appears reasonable to conclude that the trapeziform plates are, as Peach has previously surmised, the "coxae" (i.e. protopodites) of biramous limbs.

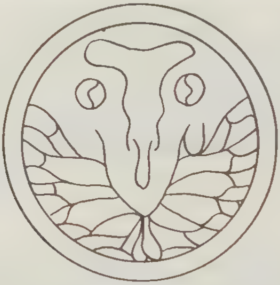

FIG. 12.—*C. rankini* after Woodward. 1868. Enlarged.

No details of the several articulations have been preserved, yet it is almost certain that they were effected by arthrodial membranes of the usual type.

The protopodites seem to have had very little movement allowed to them, for they are always found in the positions shown in the figures. This would hardly be the case were they not firmly fixed to the sternite and to the endophragmal system. On the other hand the rami were freely moveable. This is reflected in the ease with which they became detached from the dead animals. Such freedom of movement is a necessity in limbs used for swimming or for crawling, and most probably the limbs of *Halicyne* were used for both.

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[1] H. Woodward, GEOL. MAG., 1894, p. 535.

In his paper of 1894, Woodward describes and figures a specimen of *C. testudo* from the Calciferous Sandstone Shales of Eskdale. On the left-hand side of the figure is a forked structure which simulates a limb with two branching rami. "The branching of the two rami may be due to rod-like deposits of lime in a paddle-shaped fin, two such structures being attached to each limb representing the endopodite and exopodite."[1] He also refers to "numerous broken fragments of appendages scattered over the surface of the matrix [which] appear to have been of the same kind". A careful scrutiny of material from the same locality gave me the impression that these scattered fragments would prove to be calcified plant remains, probably pieces of *Archaeocalamites* or *Pinnularia*, and an examination of the specimen described by Woodward does not seem to afford any reason for changing this opinion.

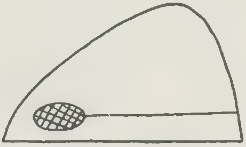

Fig. 13.—*Cyclus communis* Rogers. Diagram showing position of supposed compound eye. Enlarged. After Rogers.

The V-shaped median plate was, according to Woodward, "either the coalesced sternites or an enormously developed labrum. . . . Against the first view," he adds, "we have the fact that this structure is apparently continued without a break up to the anterior margin of the ventral surface, thus giving no place for the mouth." Since the true labrum and metastoma have been found there can be no doubt that this plate really is the fused sternites. It is, on an average about 11 mm. long and 5 mm. wide next the metastoma. As far as the fourth pair of limbs it tapers gradually, after which it comes rapidly to a point in front of the proximal ends of the seventh pair.

On either side of the sternite are two circular apparently cup-like structures. These belong to the ventral surface. In the diagram they are surrounded by a clear oval space bounded by a broken line. This space is the projection of the prominences of the *dorsal* surface, and it is seen that the ventral circles and the dorsal prominences correspond to each other in position. Now Woodward interpreted the prominences as attachments for a powerful musculature which served ventral suckers similar to those found in recent fish-lice. It is suggested that the circles are the suckers themselves, and that the rims would be hard and stiff whilst the floor would be flexible. Muscles acting as in Fig. 11 would make such an arrangement a very efficient sucker.

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[1] H. Woodward, Geol. Mag., 1894, p. 534, fig. 2, footnote.

Woodward had seen the circles and depicted them in his figure of *C. rankini.* He then termed them " eyespots ", and when, in later years, he explained the use of the prominences he does not appear to have connected the two structures.

Each sucker is anterior to two plates which are evidently in close relation to it and to each other. They are fitted into the angles between the sternite and the anterior pair of limbs. The innermost has two straight sides, one next the sternite and the other next the limb. Its periphery is completed by a curved border like a distorted question mark. On the outer side, and next the curved margin, is the second plate. This is almost an isosceles triangle with the vertex directed inwards and backwards and with the base curved so as to fit closely to the sucker. These triangles may correspond to the protopodites which follow them, and possibly the suckers are modified terminal segments which, together with the triangles, form the first thoracic limb.

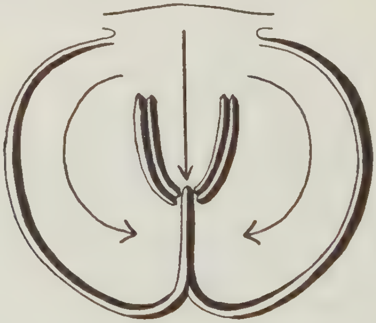

Fig. 14.—Diagram illustrating how the carapace of *Halicyne* may have arisen from the fusion of three pleurae. The arrows indicate the directions of growth.

The use and meaning of the innermost of the two plates is unknown.

In several specimens there is retained in place behind the posterior limbs a pair of flattened appendages which project beyond the margin of the carapace. These structures, when present, are always very distinct, but in every case the terminal body segment with which they articulate is very badly crushed. Taken together the segment and plates form a telson and caudal fork.

No further external details of *Halicyne* have been made out, but mention must be made of a specimen, doubtfully referable to *H. scotti* from Ilkeston, Derbyshire. In this example the ventral test is seen from the dorsal aspect and the sternite is hidden by a broad straight ridge. The ridge is slightly constricted at first in the neighbourhood of the mouth, and again where it ends in the position of the anus. Its extreme width is one-seventh of its length. The surface is creased and wrinkled in such a way as to suggest a thin-walled tube which has been filled with pasty material, and which has been subjected to a not very great pressure. A tube occupying the position indicated is, naturally, referable to the alimentary canal, and the fossil itself probably displays the muddy contents.

(γ) *Eyes.*

None of the specimens examined retain any structures of the nature of eyes. Woodward mentions "a paired small appendage, having somewhat the appearance of a stalked eye, but showing no facets [which] is present near the anterior margin of the shell".[1] The appendage is clearly shown in his figures, but the fossils themselves leave no doubt that it is the basal joint of the antennae, the rest being lost. Rogers reports the presence of compound eyes resembling those of trilobites and corresponding in position to the lateral eyes of *Limulus*.[2] These structures, which he does not figure in detail, are stated to occur in *C. communis*, but I could not find them in the two examples which I studied. Judging from the diagram given by Rogers, they are homologous with the dorsal prominences of *johnsoni* or *scotti*.

V. AFFINITIES.

Since *Halicyne* possesses antennae, biramous limbs, a telson, and a caudal fork there can be no doubt that it is a crustacean. The Arachnida always have the first pair of appendages developed as chelicerae, their so-called telson is post-anal, and they never have a caudal furca. Nevertheless it is imperative that the work of previous authors should be discussed, if only for the reason that hitherto *Halicyne* has been regarded as in some way ancestral to the limuloids, and that it is classed with the Xiphosura in such works as Eastman-Zittel.

Dr. Peach was the first to point out the biramous nature of the limbs. Regarding the general characters he says, "the radiating lines of the sternum are most probably the divisions between the coxae, so that I am inclined to differ from Woodward and to look upon the opposite end to what he does as being the anterior."[3] He accepted the Xiphosuran nature of the fossil and regarded the coxae as gnathobases converging towards the mouth.

Packard gave a similar description of the limb-bases of *C. americanus* and, in placing his new family of the Cyclidae among the Xiphosura, he expressed the opinion that it was possibly ancestral to *Limulus*.

Doubtless both these writers were influenced by the latter's researches on the development of *Limulus*. Certainly the diagram by which Packard illustrates the arrangement of the limbs of the "trilobite larva" is very like the appearances on the underside of

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[1] H. Woodward, GEOL. MAG., 1894, p. 533, pl. xv, figs. 7–8.

[2] A. F. Rogers, op. cit., supra.

[3] B. N. Peach, op. cit., supra.

Halicyne. On the other hand, the various structures represented in Fig. 7 show that this resemblance is deceptive, at least in so far as anterior and posterior are concerned.

Clarke and Ruedemann point out that crustacean characters are entirely absent in the ontogeny of *Limulus*, and also in that of the Eurypterids.[1] Now *Halicyne* has several well-marked crustacean characteristics, therefore it cannot be an immediate precursor of *Limulus*, nor does it appear advisable to include them in the same group.

To find a suitable position among the Crustacea which shall express the natural relationships of the genus is a matter of some difficulty. The solution here given is provisional only. It is one, however, which seems to cover the facts so far as they are known.

Woodward suggests, " that it is an Entomostracan, and probably one of the Phyllopoda, with a broad cephalic carapace like that possessed by *Apus* and by *Daphnia*." The term Entomostracan has no precise meaning in Zoology, but, in the sense that *Halicyne* is not Malacostracan, Woodward was right; there is no suggestion of a caridoid facies. " One of the Phyllopoda " cannot be conceded. The limb of *Halicyne* consists of a large protopodite together with an endopodite and exopodite, both of three segments; a very different organ from the lobate, leaf-like appendage to which the term " phyllopod " is applied.

Excluding the Malacostraca and also, for reasons which are self-evident, the Cirripedia, there remain to be considered the Branchiopoda, Cladocera, Ostracoda, Copepoda, and Leptostraca. By means of a process of elimination it may be possible to select that order which will receive *Halicyne* with the least difficulty. The first two constitute the old group of the Phyllopoda and on that ground must be rejected. The Ostracoda with a bivalve shell, only two pairs of thoracic limbs, and the hinder end of the body rudimentary are equally unsatisfactory. Leaving the Copepoda on one side for the moment, there are the Leptostraca; they have a bivalved carapace, foliaceous thoracic and biramous abdominal limbs, together with antennules and antennae. Such an assemblage of characters is not found in *Halicyne*.

The Copepoda have been left for the last because it it here that *Halicyne* seems to fit in with a minimum of effort; not among the Eucopepoda but among the Branchiura, or fish-lice, of which *Argulus* is the most familiar. There are differences in structure between *Argulus* and *Halicyne*, and it may be that the resemblances are due to convergence. They both agree in possessing a small number of biramous swimming limbs, suckers for attachment to foreign bodies, and a carapace. They differ in the character of the antennae, which form stout hooks in *Argulus*, in the caudal fork, and in the carapace. On the other hand, the limb of *Halicyne* has a

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[1] Clarke and Ruedemann, *The Eurypteridea of New York*, Memoir 14, N.Y. State Museum, 1912.

great deal in common with that of a typical Copepod such as *Cyclops*. Thus they both have a protopodite of two joints, one of which in *Halicyne* is rudimentary ; each ramus consists of three segments, and in both the limbs are natatory.

In the *Branchiura* the carapace is really a pair of lateral pleurae arising from the back of the head. It is to be noted therefore that the shell of *Halicyne* is capable of analysis into three lobes which have fused, the sutures being indicated by the median ridge and its branches.

For these reasons then, the family Cyclidae is included with the Copepoda Branchiura.

VI. HABITS.

That *Halicyne* was a free-living animal, which crawled on the bottom and fed on decaying organic matter, is shown by the mud-filled gut. At the same time the depressed shell and the presence ot suckers seems to indicate that the animals lived under such conditions that there was a swift flow of water relative to themselves. Swift currents are not usually associated with the deposition of the Coal Measures. If, however, *Halicyne* was ectoparasitic on occasion, and infested the fish of that period, the movement of the host through the water would necessitate some such mechanism to lessen the chances of the parasites being swept off whilst feeding on the mucus which covered the scales.

VII. REVISION OF GENERA AND SPECIES.

As the work progressed it became evident that there were two groups of species involved which seemed sufficiently distinct for them to be regarded as genera. The first group consists of *radialis* and its congeners, to which *Cyclus* is restricted. The second group contains *johnsoni* and similar species. It was found that two of the species of this group, *agnotus* and *laxus*, had been described by von Meyer as belonging to the genus *Halicyne*. In 1870, Woodward rejected von Meyer's genus as a synonym of *Cyclus*, but I propose to resuscitate it.

At present there are some seventeen species divided between the two genera ; these are enumerated below. In most cases the carapace is all that is known, and it is doubtful as to how far the ornamentation can be relied on as indicating the relationship between the species. It seems preferable, therefore, to give an alphabetical list instead of a "systematic" arrangement for which the evidence is insufficient.

Class.—**CRUSTACEA**
Sub-class.—*COPEPODA*.
Order.—BRANCHIURA.
Family.—CYCLIDAE.
Genus : *Cyclus* de Koninck, char. emend. infra.

Carapace small, oval to subcircular, inflated, often hemispherical, bilaterally symmetrical, with a posterior median ridge, or furrow, which may extend for more than half the length of the test, and which may bifurcate to enclose a triangular median area at its anterior end. Ornament lobate, ribbed, or nodular; often pustulate or granulate; margin usually smooth; appendages unknown, possibly seven pairs of biramous limbs.

1. RADIALIS (Phillips). Genotype.

Agnostus ? radialis Phillips, 1836.
Cyclus radialis de Koninck, 1841, 1842.
Cyclus radialis H. Woodward, 1868, 1870, 1878, 1894.
Carboniferous Limestone, Bolland, Yorkshire.[1]

2. BILOBATUS H. Woodward.

Cyclus bilobatus H. Woodward, 1870, 1878.
Carboniferous Limestone, Settle, Yorkshire.

3. COMMUNIS A. F. Rogers.

Cyclus communis Rogers, 1902.
Upper Coal Measures, Iola Limestone, Kansas City, Mo.

4. HARKNESSI H. Woodward.

Cyclus harknessi H. Woodward, 1870, 1878.
Carboniferous Limestone, Little Island, Co. Cork.

4*a*. HARKNESSI WOODWARDI Cowper Reed.

Cyclus woodwardi Cowper Reed, 1893.
Cyclus woodwardi H. Woodward, 1894.
Carboniferous Limestone, Settle, Yorkshire.

These two forms (4, 4*a*) together with *radialis* are of especial interest since they afford some slight evidence of the structure of the animals to which the tests belonged. In each there are seven pairs of radiating ribs on the carapace. The ribs are variously ornamented, but their disposition is in exact agreement with that of the protopodites of *johnsoni*. This appears to confirm Woodward's opinion that the ribs on the carapace covered the limbs and corresponded to them in their arrangement.

The differences between *harknessi* and *woodwardi* are slight, and the form described by Reed seems to be nothing more than a variety of *harknessi*.

5. JONESIANUS H. Woodward.

Cyclus jonesianus H. Woodward, 1870, 1878, 1894.
Carboniferous Limestone, Little Island, Co. Cork.

6. MINUTUS A. F. Rogers.

Cyclus minutus Rogers, 1902
Upper Coal Measures, Iola Limestone, Kansas City, Mo.

7. TOROSUS H. Woodward.

Cyclus torosus H. Woodward, 1870, 1878.
Carboniferous Limestone, Little Island, Co. Cork.

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[1] The horizon and locality is, in each case, that of the *type specimen.*

8. WRIGHTI H. Woodward.

Cyclus wrighti H. Woodward, 1870, 1878.

Carboniferous Limestone, Little Island, Co. Cork.

Genus.—*Halicyne* von Meyer, char. emend. infra.

Carapace usually larger than in *Cyclus*, depressed, subcircular, slightly broader than long; median posterior ridge always bifurcate, bifurcation double, each branch having an inner and an outer ridge; ornament usually punctate, seldom lobate, margin as in *Cyclus*. One pair of long, uniramous antennae, with a multiarticulate flagellum; seven pairs of biramous swimming limbs, each ramus of three segments and furnished with natatory setae (?); caudal furca of two elliptical plates, each with a longitudinal mesial ridge. Labrum large, subfusiform; metastoma a simple, crescentic ridge; abdomen, with the exception of the telson, concealed by the carapace.

1. AGNOTA von Meyer. Genotype.

Olenus serotinus Goldfuss MS.
Limulus agnotus v. Meyer, 1838
Halicyne agnota v. Meyer, 1844.
Cyclus agnotus H. Woodward, 1870.

Muschelkalk, Rottweil, Germany.

2. AMERICANA (Packard).

Cyclus americanus Packard, 1885, 1886.
Cyclus americanus Rogers, 1902.

Lower Coal Measures, Mazon Creek, Illinois.

This form is only known from the type specimen which shows the margin, a cast of the gut, and the divisions between the posterior protopodites. The figures given by Packard, and reproduced by Eastman-Zittel, are upside down and, as has been explained above, the reference to " mouth parts " is faulty.

3. JOHNSONI (H. Woodward).

Cyclus johnsoni H. Woodward, 1894.

Pennystone Ironstone, Cosely, nr. Dudley, Staffs.

4. LIMBATA (A. F. Rogers).

Cyclus limbatus Rogers, 1902.

Upper Coal Measures, Iola, Limestone, Kansas City, Mo.

5. PACKARDI (A. F. Rogers).

Cyclus packardi Rogers, 1902.

Upper Coal Measures, Iola Limestone, Kansas City, Mo.

6. PERMARGINATA (A. F. Rogers).

Cyclus permarginatus Rogers, 1902.

Upper Coal Measures, Iola Limestone, Kansas City, Mo.

This species is said to have a serrated margin comparable to that found in *Limulus*. To judge from the figure and from similar appearances found occasionally in *H. johnsoni* and *H. scotti* the serrations are the extremities of contracted limbs.

7. SCOTTI (H. Woodward).

Cyclus scotti H. Woodward, 1893, 1894.

Lower Coal Measures, Bacup, Lancashire.

This appears to be the common species in the Dudley Coalfield, although the specimens are usually smaller than the type. The common form in Lancashire is *johnsoni*, which was first described from a Staffordshire example.

The following " species " are either of doubtful value, or else to be rejected :—

1. *Cyclus brongniartianus* de Koninck, 1842.

Bronn includes this species in his Index, with the remark " Phillipsiae hypostoma aut epistoma, teste Barrande 1847 in litt."[1] If reference be made to de Koninck's original figure, it will be seen that there is no doubt that the object there represented is not one of the Cyclidae but the hypostome of a trilobite.

2. *Halicyne laxa* H. von Meyer, 1844.

In Bronn this is shown as being synonymous with *Limulus priscus* Münster. Mr. C. D. Sherborn informs me that " *laxa* seems merely a *nomen nudum*, and if you can identify it with *priscus* then *priscus* stands ; if not *priscus* stands and *laxa* is indeterminate." Woodward figured a form as *laxa* in 1870, and a comparison with the figure of *L. priscus* in Zittel shows that the two animals are wholly dissimilar. Hence *laxa* is to be rejected as indeterminate.

3. *Cyclus rankini* H. Woodward, 1868.

As was first pointed out by Peach this form is the ventral surface of some form of *Cyclus* (Halicyne). There is nothing to differentiate it, but the name might be retained as a convenient label for specimens in a similar state of preservation.

VIII. CONCLUSION.

In this paper the history of the genus *Cyclus* is outlined ; the organization of *C. johnsoni* is described and illustrated, and the antennae, limbs, labrum, metastoma, telson, and caudal fork made known in detail for the first time. Reasons are given for looking on the genus as Crustacean and for including it with the Copepoda Branchiura. For the reception of certain forms the genus *Halicyne* von Meyer has been revived.

I am indebted to the authorities of the British Museum (Natural History), the United States National Museum, and of the Manchester Museum for the loan of much very valuable material, and to Professor O. T. Jones and Mr. J. Wilfrid Jackson, M.Sc., for their help in obtaining these specimens.

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[1] H. G. Bronn, *Index Palaeontologicus*, Bd. 1, Abth. 1, p. 380.

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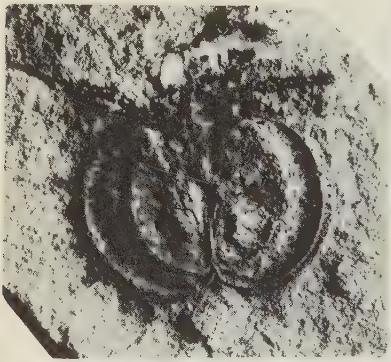

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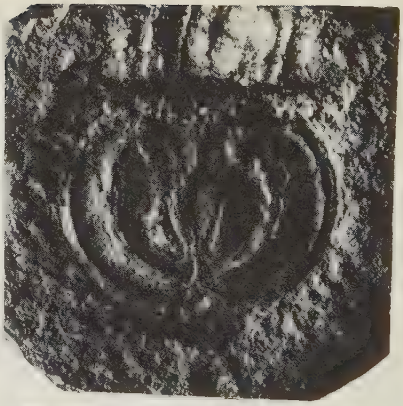

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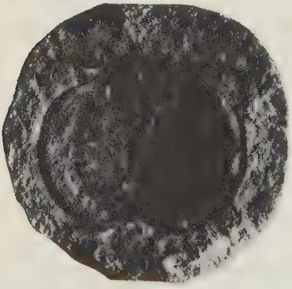

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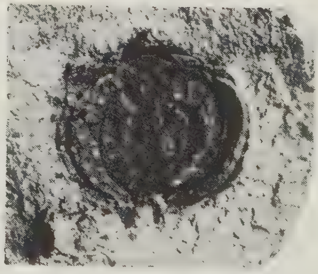

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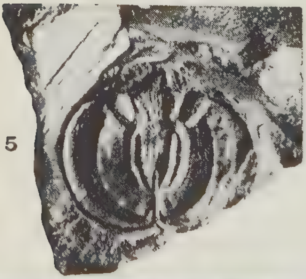

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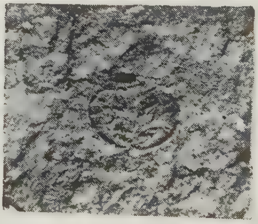

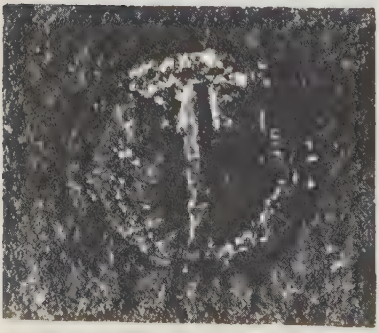

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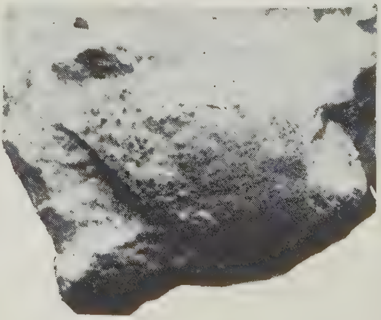

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H. Britten photo.

BRITISH AND AMERICAN *CYCLIDAE.*

To face p. 309.]

I wish also to express my best thanks to Professor G. Hickling for his kindly interest and advice, and to Mr. Sherborn for elucidating the synonymy of v. Meyer's forms.

Note.—Since the above paper was written, Mr. E. Leonard Gill has published a description of an example of *Halicyne johnsoni* from the Newcastle Coalfield. He has very kindly prevailed upon Mr. Eltringham, the owner of the specimen, to lend it to me for examination. Unfortunately I do not agree with Mr. Gill in his interpretation of the " mouth-parts " and I hope to discuss the fossil in a subsequent paper.

EXPLANATION OF PLATE XI.

FIG.

1.—*Halicyne johnsoni* (H. Woodw.). Middle Coal Measures, Sparth, Rochdale. Dorsal aspect. Nat. size. L11753(B), Mus. Manc.

2.—*H. johnsoni* (H. Woodw.). Middle Coal Measures, Sparth, Rochdale. Dorsal aspect. Nat. size. L8185, Mus. Manc.

3.—*H. johnsoni* (H. Woodw.). Middle Coal Measures, Sparth, Rochdale. Dorsal aspect. Nat. size. L7098, Mus. Manc.

4.—*H. johnsoni* (H. Woodw.). Middle Coal Measures, Sparth, Rochdale. Mouth region and caudal fork preserved. Nat. size. L11754, Mus. Manc.

5.—*H. scotti* (H. Woodw.). Lower Coal Measures, Bacup, Lancashire. Type specimen. Nat. size. L10220, Mus. Manc.

6.—*H. testudo* (Peach). Calciferous Sandstone Series, Eskdale, Dumfries. Dorsal aspect. Nat. size. In22386, B.M. (N.H.).

7.—H. ? *scotti* (H. Woodw.). Coal Measures, Shipley Clay Pit, near Ilkeston, Derbyshire. Showing cast of gut and protopodites. × 3. In18591, B.M. (N.H.).

8.—*Cyclus communis* Rogers. Upper Coal Measures, Iola Limestone, Kansas City, Mo. Test preserved in white limestone. × 3. Reg. No. 35050, U.S. Nat. Mus.

Petrographical Notes on some Chloritoid Rocks.

By C. E. Tilley.

(PLATES XII AND XIII.)

I. A Chloritoid Andalusite Schist from Eyre Peninsula, South Australia.

CHLORITOID-BEARING schists have so far not been recorded from the State of South Australia, though such are known from the Pre-Cambrian rocks of the Broken Hill area. The chloritoid rocks now to be shortly described occur interbedded with quartzites, forming the meridional ridge of the " Frenchman ", on the western coast of southern Eyre Peninsula. In a previous paper (1)[1] the rocks of this area have been referred to, as comprised within two groups, a sedimentary series—the Warrow series, and the Dutton series, a group of acid granites of gneissic habit with associated aplites and pegmatites, often rich in tourmaline and carrying garnet, and beryl. These rocks invade the sediments of the Warrow series.

At the locality of the Frenchman, the sediments, mica schists, and quartzites, have been intimately penetrated by the invading

[1] Numbers in parentheses refer to the bibliography at the end of the paper.

magma producing at the immediate contact a zone of injection-gneisses. The chloritoid schists are developed within the aureole, and this fact adds interest to the occurrence of this mineral when the question of genesis is considered.

These chloritoid schists are intercalated in the thick quartzite of the Frenchman ridge, and exposed to view near the summit of the ridge itself. The rocks dip at an angle of 45 degrees east. The relations are diagrammatically shown in the accompanying sketch (Fig. 1). The rocks are typical crystalline schists, grey white in colour and spotted with black mica-like crystals. The structure is typically porphyroblastic, with a nematoblastic groundmass.

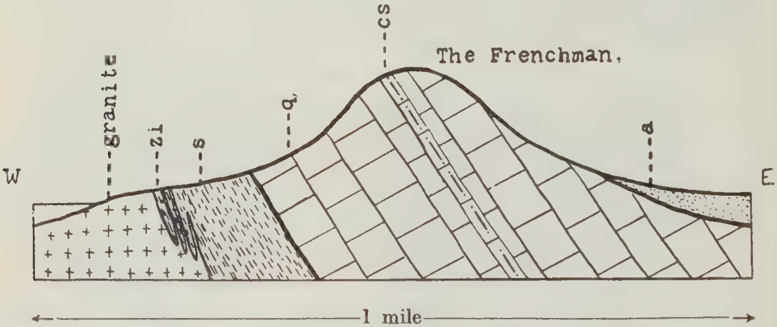

FIG. 1.—Section across the quartzitic ridge of the Frenchman. *zi*=zone of injection, *s*=schists, *q*=quartzites, *cs*=chloritoid schist, *a*=alluvium, etc.

The constituent minerals are quartz, muscovite, chloritoid, with accessories, andalusite, tourmaline, sphene rutile. Some of them contain chlorite, but this mineral in many cases is wholly absent.

Chloritoid.—In hand specimens this mineral appears in flakes of black colour with mica-like habit. It is brittle, and has a hardness of 6. Under the microscope, basal sections show a rude hexagonal outline, whilst longitudinal sections are rectangular. There is a well-developed basal cleavage and an imperfect cleavage whose trace in sections perpendicular to 001 is at right angles to the base, corresponding to a plane in the prism zone or a steeply dipping pyramid. Pleochroism is strong, as follows—

X olive green, Y pale blue, Z yellowish green.

Further, $Y > X > Z$ and dispersion $\rho > v$.

The mineral is optically positive, with the acute bisectrix emerging nearly perpendicular to the 001 cleavage. It is multiply twinned on the mica law, the individual lamellae being narrow. Common extinctions are 25 degrees in one lamella accompanied by extinctions of 15 degrees in the adjacent. The former is probably the extinction for a section parallel to 010, and the latter for a section parallel to 110. Mean refractive index 1·73, and birefringence ·007.

There is no hour-glass structure, and no indications of alteration. The common enclosures in the chloritoid are quartz, rutile, andalusite, and tourmaline.

The andalusite is occasionally developed in porphyroblasts, but never idioblastic, being always broken up and irregular in outline. It is in process of resolution to sericite in many examples. It is frequently in association with the chloritoid, either partially or wholly enclosed within this mineral.

Tourmaline is sometimes abundant, often well shaped, and frequently enclosed in chloritoid. It is frequently zoned, with a blue core, the pleochroic colours being O olive green, E pink, corresponding to the iron-bearing type. There can be no doubt, from its abundance and associations, that its source is the adjacent igneous magma.

An analysis of one of these chloritoid schists has been made, and is given below with analyses of other chloritoid schists of similar silica content. The analysis of a sericite schist of closely analogous chemical composition is also given.

	(i)	(ii)	(iii)	(iv)	(v)
SiO_2 .	74·48	73·54	76·90	78·88	73·45
Al_2O_3	15·96	14·40	15·02	10·75	13·77
Fe_2O_3	0·87	4·59	0·50	1·05	2·76
FeO .	2·02		4·72	2·74	
MgO	0·35	0·50	0·58	1·67	1·22
CaO .	0·28	0·02	0·50	0·10	—
Na_2O	0·72	0·44	0·11	1·26	0·18
K_2O .	3·88	2·11	0·01	1·85	4·47
H_2O +	2·02	1·96	1·30	1·49	3·08
H_2O —	0·13	0·24	—		
Access.	n.d.	2·37	0·20	1·20	0·24
	100·71	100·17	99·84	100·99	99·17
Minerals present (accessories).	Quartz, Sericite, Chloritoid (andal., rut., tourm.).	Quartz, Sericite, Chloritoid (chlor., rut., iron-ore).	Quartz, Chloritoid, Chlorite (ep., tit., mgt.).	Quartz, Sericite, Chloritoid, Chlorite (rut., mgt., ep., tourm.).	Sericite Schist. Schaller, cf. Clarke, *Bull. U.S.G.S.* No. 419, p. 30.
	The Frenchman. Eyre Peninsula, S. Austr.	Gotthard massiv. Niggli, p. 50. (*Beitr. geolog. Karte der Schweiz*, N.F., xxxvi, 1912.)	Potaro River, Guiana. Harrison, 1908, p. 61. (*Geology of Br. Guiana.*)	Alpi Apuane. Manasse, cf. Niggli, op. cit., p. 85.	

It is to be observed that mineralogically the quoted chloritoid schists differ from the analysed Frenchman rock in the presence of chlorite, which is conspicuous by its absence in the latter rock. Chemically they are distinguished by a higher content of iron oxides and a distinctly lower content of alkalies, which are very subordinate in the British Guiana rock where no sericite is present. In the Frenchman chloritoid schist, chloritoid is present to the extent of 9 per cent, andalusite 1 per cent, sericite 33 per cent, and quârtz 57 per cent.

The outstanding features of this area of crystalline schists and associated igneous gneisses are (*a*) the zone of injection-gneisses, (*b*) the concordant nature of the intrusions.

The development of gneisses of injection origin at the contact of granites and argillaceous sediments pre-supposes certain conditions which are to be fulfilled before such rocks can arise.

In the first place there is necessitated a high fluidity of the liquid magma, and further that the invaded rocks are already heated to enable intrusion to proceed without premature consolidation through rapid cooling. Lastly, the structure of the invaded sediment must already be such that planes of minimum cohesion are available for the penetrating solutions. These last prerequisites imply that the invaded sediment is already metamorphosed

The concordant nature of the intrusions, their gneissic texture, and the habit of the contact rocks as crystalline schists are all clearly indicative of igneous intrusion during an epoch of orogenic disturbance.

The metamorphism induced in the surrounding sediments is then not that of normal contact metamorphism, but a metamorphism of thermal dynamic type. These conditions may be appropriately described under the term piezocontact metamorphism. Especially characteristic of such intrusions is the high content of water and other mineralizers. In the present case this character is attested by the abundant presence of muscovite, both in the igneous rocks and in the adjacent sediments, and of tourmaline.

The argillaceous sediments in the aureole, apart from the injection gneisses, are now biotite schists, quartz muscovite andalusite schists with and without pneumatolytic tourmaline, in some of which magnetite occurs in prominent crystals, and the chloritoid schists already described.

In the andalusite rocks of this region a potash felspar finds no place as a metamorphic mineral. Its place is taken by the abundant muscovite. It is scarcely conceivable that in rocks of this type andalusite has arisen from kaolin, a production from sericite in some such manner as is indicated in the following equation appearing more probable—

$$2H_2KAl_3Si_3O_{12} \rightarrow 3Al_2SiO_5 + 2KOH + 3SiO_2 + H_2O$$

Indeed, the very common conversion of andalusite to muscovite may indicate that a reaction of this type is reversible, and that at lower temperatures the reconversion of andalusite to white mica proceeds. The point of greatest interest, however, in the rocks is the association chloritoid-andalusite. Andalusite is usually regarded as one of the typical anti-stress minerals, whilst chloritoid is characteristically present in dynamically metamorphosed rocks. Typical occurrences of chloritoid in such rocks, are those of the Belgian Ardennes (2), and the Swiss chloritoid rocks of the Gotthard-massiv (3).

In the rocks now under consideration, two points may be noted, first the enclosure of pneumatolytic tourmaline by chloritoid, and secondly, the presence of irregular and frayed grains of andalusite within chloritoid, and where not so enclosed its very general partial conversion to muscovite.

In none of the schists examined is there clear evidence of the manner in which the chloritoid has arisen. That it was crystallizing subsequent to the introduction of tourmaline is clear, and its relation to andalusite suggests that in part at least it is built up from andalusite. Much of the chloritoid is, however, independent of andalusite. Two possible reactions suggest themselves:

(*a*) $Al_2SiO_5 + Fe(OH)_2 \rightarrow H_2FeAl_2SiO_7$

(*b*) $2H_2KAl_3(SiO_4)_3 + 3Fe(OH)_2 \rightarrow 3H_2FeAl_2SiO_7 + 2KOH + 3SiO_2 + H_2O$

The source and manner of introduction of the ferrous iron is not revealed.

It is not necessary to suppose that chloritoid was developed at a stage long posterior to the formation of andalusite. In the history of the orogenic disturbances associated with the granitic intrusions, the relations of the physical conditions of pressure and temperature would undoubtedly be complex. It would be in harmony with the facts to believe that during the metamorphic epoch, andalusite developed at a stage corresponding to a maximum temperature of the sediments, and that chloritoid arose, subsequent to the pneumatolytic penetration of tourmaline, at a period corresponding to increased shearing stress and falling temperature, and partly at the expense of earlier formed andalusite.

Chloritoid- or ottrelite-andalusite rocks have been previously described from a number of localities in other areas. Such rocks were first recorded by Götz (4) from Mt. Maré in the Marabastad area in the northern Transvaal. These rocks have since been further investigated by Hall, who has also described andalusite ottrelite rocks from the aureole of the Bushveld complex (5), and from the Barberton district (6). Ottrelite is rare in the Bushveld aureole, but abundant in the Barberton and Mt. Maré districts, where intrusion was accompanied by tectonic disturbances. In the original description Götz ascribed both andalusite and ottrelite[1]

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[1] Described as "ottrelite" by Götz, but his analysis of this mineral (op. cit., p. 145) is clearly that of a chloritoid.

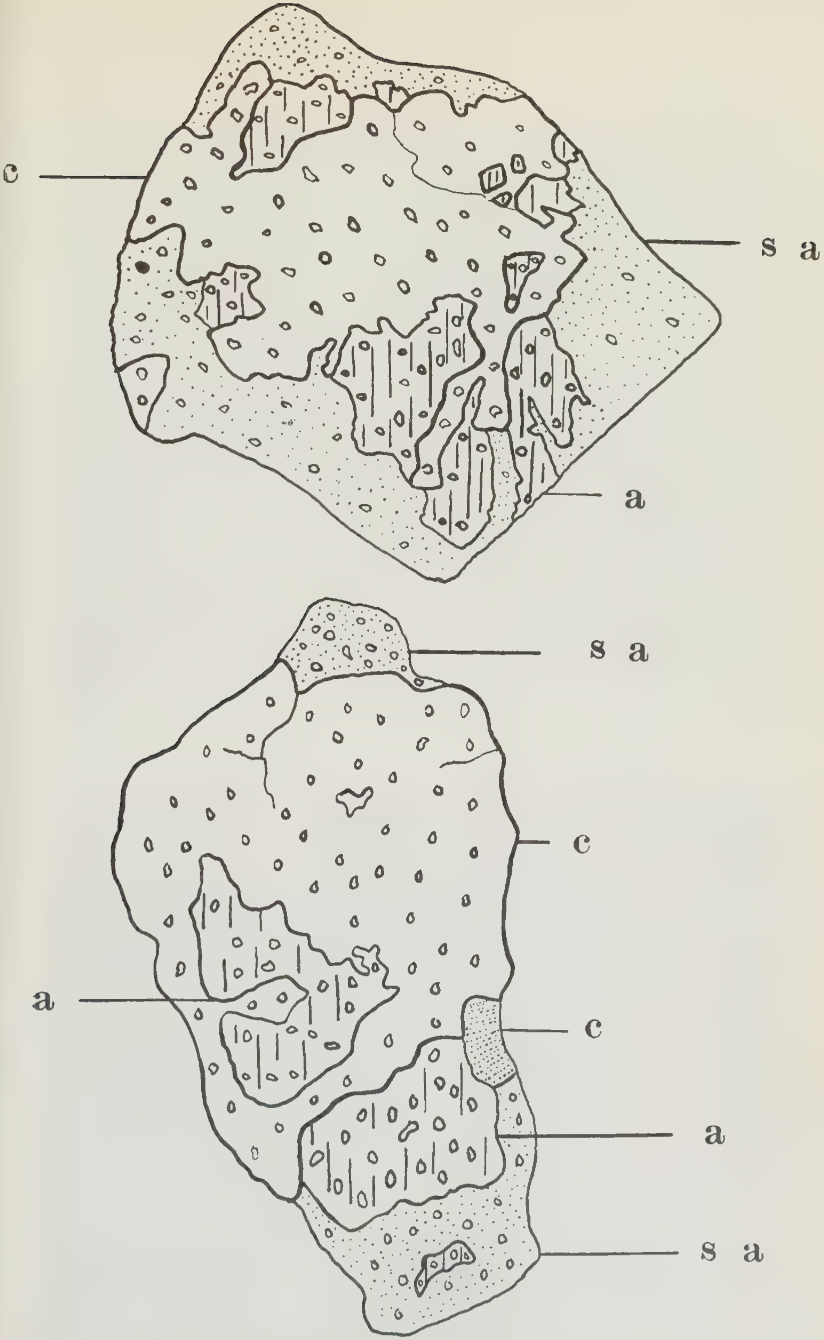
(chloritoid) as products of dynamic metamorphism, but Hall shows that they are developed in the vicinity of igneous intrusions. Both minerals are ascribed to the contact metamorphism. Whilst this may be generally correct, it is not necessary to suppose that both arise under identical physical conditions or simultaneously. Indeed, the evidence of tectonic disturbance supplied by these areas, warrants a careful examination in the light of successive development. An ottrelite or chloritoid is developed in the slates of the Skiddaw area and has been recorded by Rastall (7). This mineral is found in the slates and flags, both in thermally unaltered rocks and at the outermost edge of the Skiddaw granite aureole, where it is associated with chiastolite. As Rastall has indicated the chloritoid here belongs clearly to an earlier period of dynamic metamorphism, and is destroyed by the contact action of the Skiddaw granite.

Chloritoid andalusite schists occur in the Broken Hill area of New South Wales, and these provide very instructive illustrations of the genetic relations of the two minerals. These rocks have undoubtedly had a complex history, indicated not only by the mineralogic associations, and their mineralogic textures, but also by the large number of minerals found in intimate association. One rock recorded from Mt. Robe (8) is described as containing in thin slice, quartz, muscovite, biotite, andalusite, sillimanite, chloritoid, chlorite, garnet, magnetite, and tourmaline. Such a mineral association is clearly one in which equilibrium is far from being completely attained, and the associations bear witness to this great departure from equilibrium conditions. The relations of the andalusite and chloritoid are such that there can be no doubt that chloritoid is arising from earlier developed andalusite.

From a thin section of the Mt. Robe rock, a specimen of which was kindly presented by W. R. Browne, the relations of these two minerals have been figured and are shown in the two accompanying drawings (Figs. 2, 3). The original andalusite enclosed numerous grains of quartz. Through it are developed masses of chloritoid in such a way as to indicate clearly that the latter mineral is arising on the ruins of the andalusite. Isolated masses of andalusite are enclosed in the chloritoid, and these possess the common optical orientation of the original crystal. Much of the original andalusite has been sericitized. These examples provide very convincing evidence of the andalusite-chloritoid reaction. Even here, however, the manner of introduction and origin of the ferrous iron is not clearly revealed.

II. CHLORITOID PHYLLITES OF THE TINTAGEL AREA, NORTH CORNWALL.

Chloritoid (ottrelite) was first described in Britain by W. M. Hutchings (9) in the slates of Tintagel. His examples were obtained from the quarry close to Tintagel church on the coastal cliff. Since that time the Geological Survey has mapped chloritoid phyllites



Figs. 2 and 3.—Chloritoid developing from andalusite in chloritoid-andalusite Schist, Mt. Robe, Broken Hill area, N.S. Wales. *c* = chloritoid, *a* = andalusite, *sa* = sericitized andalusite.

over a wider area in this district. The Woolgarden phyllites are regarded as the home of the chloritoid. However, chloritoid is not limited to any particular horizon as I have observed it, both in the Delabole slate group, and that of the Tredorn phyllites. Hutchings has given in the paper already cited an excellent petrographic description of the chloritoid (ottrelite)[1] slate of the coast quarry, and this needs no enlargement here. Not only, however, do the chloritoid and ilmenite develop characteristically at angles to the foliation, but muscovite also is not infrequently developed with its longer axes oblique to the foliation.

The character of these chloritoid slates is shown in the accompanying photomicrograph (Pl. XIII, Fig. 1).

The Woolgarden phyllites were first described by Parkinson (10) under the name Hallwell Cottage Beds. They are described as sericitic phyllites with abundant clinochlore. The present name of this horizon is that given by the Geological Survey (11), and a petrographical description of the rocks is given in the memoir (op. cit., p. 32).

They are referred to as chloritoid phyllites, and the properties of the chloritoid given. A comparison of the Survey slides of these phyllites, and thin sections of the rocks, now in the Sedgwick Museum collection, described by Parkinson, shows that the clinochlore of Parkinson, is the chloritoid of the Survey description. Additional examples of these rocks have been collected by the writer. The mineral in question occurs in plates with irregular terminations. They are prophyroblastic and set across the foliation. Commonly an hour-glass structure is given by the arrangement of the inclusions, commonly rutile needles, and also ilmenite rods. Minute colourless but ragged rod-shaped inclusions of low refractive index are frequent, with their longer axes parallel to the foliation irrespective of the orientation of the porphyroblast. Twinning is universal and of the multiple type. Pleochroism strong, for rays vibrating parallel to the basal cleavage, it is olive green, and perpendicular thereto yellow green. The elongation is positive, and optical sign negative. The mineral is nearly uniaxial. The twin lamellæ show slightly oblique extinction. The birefringence is quite low, and anomalous indigo-blue interference colours due to dispersion are the rule. The refraction is somewhat higher than that for normal chlorites but never approximates the value common to chloritoids. These properties indicate that this mineral is a member of the chlorite group, and differs very widely from chloritoid in the character and magnitude of the double refraction, pleochroism, optic axial angle and character of the principal zone.

On the other hand, the accordance with clinochlore is not complete; the resemblance is much closer to penninite.

In some of the sections of the Woolgarden phyllites this chlorite is

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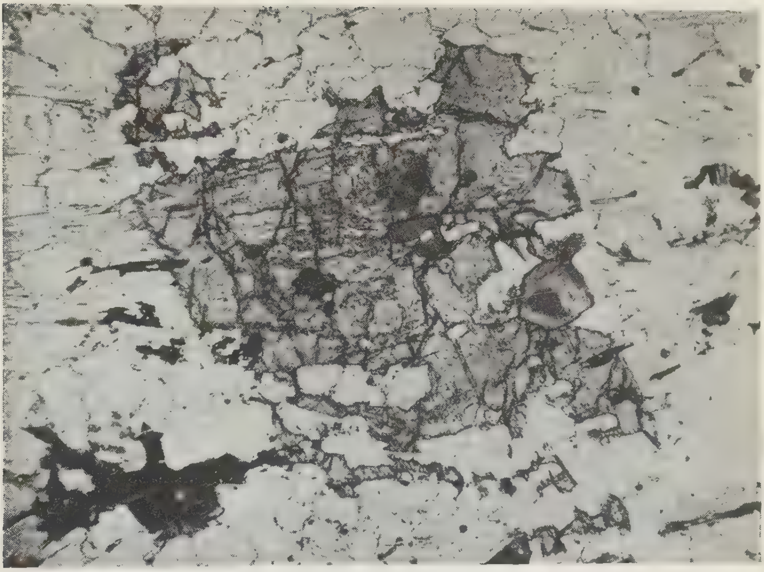
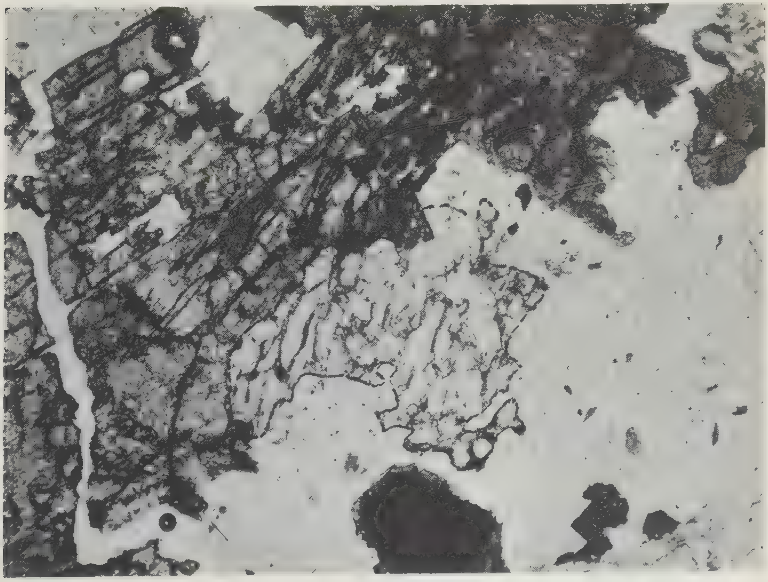
[1] Examples tested by me showed that this mineral is not manganiferous.

1



CHLORITOID SCHIST, THE FRENCHMAN, EYRE PENINSULA. × 30 diams.

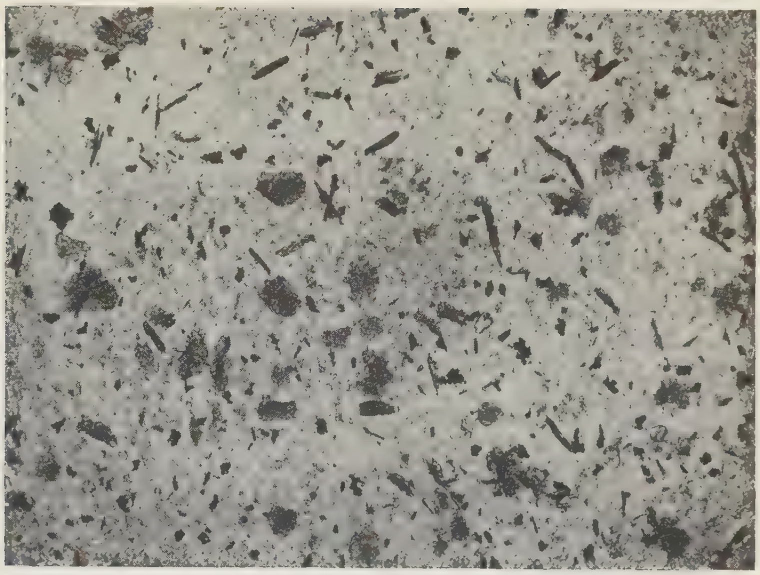
2



CHLORITOID-ANDALUSITE SCHIST, THE FRENCHMAN, EYRE PENINSULA. × 30 diams.

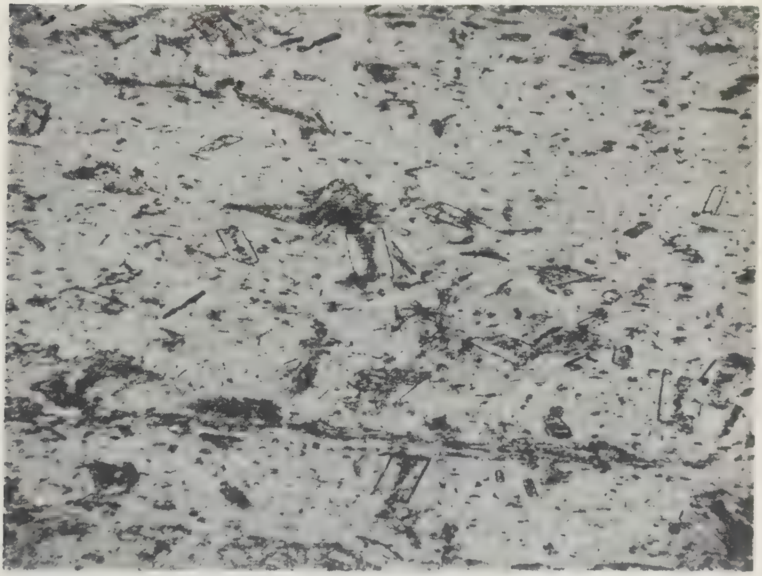
[*To face p. 316.*

1



Chloritoid Slate, Tintagel, N. Cornwall. × 30 diams.

2



Chlorite-Chloritoid Phyllite, Tintagel, N. Cornwall.
× 30 diams.

accompanied by true chloritoid, which is readily distinguished from it. As in other chloritoid rocks it is frequently intergrown in parallel with muscovite. Simple twins are the rule. A microphotograph of such a chlorite chloritoid phyllite is given in Pl. XIII, Fig. 2. Hour-glass structure is not confined to the chlorite of these rocks but may be found in the unoriented plates of muscovite. The structure here is given by numerous needles of rutile.

The chloritoid rocks of Tintagel are ascribed to contact metamorphism by Dewey (12), and in the vicinity of Tintagel an area is delimited as a contact zone. Dewey states with regard to this area : " All the rocks are contact altered. . . . There is no exposure of granite nearer than the Bodmin Moor mass which is 5 miles away ; but it is possible that an underground spur of this granite mass runs in a general north-westerly direction beneath the metamorphosed area . . . and produced the metamorphism of the overlying rocks " (op. cit., p. 278).

It is very difficult to believe that these rocks are products of thermal metamorphism. Neither in their structures, textures, nor mineralogical contents do they approximate to the normal products of thermal aureoles. I venture to believe that the chloritoid rocks are typical products of the dynamic metamorphism which clearly preceded intrusion of the great granite masses. The marked evidences of folding and cleavage, shearing, and brecciation seen in the cliff sections in the vicinity of Tintagel make it quite clear that the sediments must have undergone recrystallization during this period of movement. Not only are the argillaceous sediments typical dynamic products, but the same remark applies to the interbedded volcanic series, the textures and mineralogy of which are essentially characteristic of dynamic metamorphism.

THE PLACE OF CHLORITOID IN PROGRESSIVE REGIONAL METAMORPHISM.

Inspection of a suite of analyses of chloritoid-bearing rocks at once demonstrates the wide chemical field in which this mineral is developed. The analyses are characterized by a wide range of silica percentages (30–80), but alumina is characteristically high and lime very low. It is clear that with increasing contents of lime the formation of chloritoid is inhibited, and zoisite and epidote minerals arise in its place. Not only, however, is chloritoid stable over a wide chemical field, but it also possesses a wide physical field of stability, a further fact brought out by a study of its mineral associates. Considered from the point of view of progressive metamorphism, it is seen that chloritoid may develop at a very early stage, first appearing in the chlorite zone. Typical examples of its occurrence in this zone are the Swiss chloritoid rocks (Gotthardmassiv), the ottrelite rocks of the Ardennes, and the chloritoid phyllites of the Tintagel area of North Cornwall.

The chloritoid rocks of Drumtochty, Kincardineshire (13), occur in the higher zone of biotite. The stability field of chloritoid, in fact, extends into the still higher zone of almandine. Beyond this there is evidence that it eventually gives place to staurolite.

The conversion of chloritoid to staurolite has in fact been repeatedly observed in the chloritoid staurolite rocks of the Piz Scopi area (14), where staurolite arises from the ruins of chloritoid, with the accompanying new formation of biotite. Such a conversion can be represented by some such equation as follows:—

$$\text{Chloritoid} + \text{muscovite} + \text{quartz} \rightarrow \text{staurolite} + \text{biotite} + \text{water}$$

$$10H_2FeAl_2SiO_7 + H_2KAl_3Si_3O_{12} + SiO_2 \quad 4HFeAl_5Si_2O_{13} + \begin{pmatrix} H_2KAl_3Si_3O_{12} \\ 3Fe_2SiO_4 \end{pmatrix} + 8H_2O.$$

Ultimately then, chloritoid schists may give place to staurolite-bearing types. That this or some similar reaction is reversible is clearly indicated by Becke's observation on the production of chloritoid from the staurolite of the mica schists of the Bundschuh masse (15), and a similar change is suggested by Goldschmidt for the chloritoid in the metamorphosed rocks of the Stavanger area (16). As Becke has indicated, this reaction is a typical example of diaphthoresis.

Chloritoid in association with higher index minerals as kyanite and corundum has been recorded, the original chloritoid from the Urals in fact being found in association with kyanite. Whether the chloritoid-corundum associations recorded are in reality stable may perhaps be a point still worthy of further inquiry.

Lastly, at the highest temperatures the thermally metamorphosed equivalents of the chloritoid rocks are the cordierite and cordierite spinel (corundum) hornfelses (17).

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DESCRIPTIONS OF PLATES XII AND XIII.

PLATE XII.

FIG. 1.—Chloritoid schist, The Frenchman, Eyre Peninsula. × 30 diameters. Chloritoid set athwart the foliation, in a base of quartz and muscovite. The crystal encloses grains of zoned pneumatolytic tourmaline.

FIG. 2.—Chloritoid andalusite schist, The Frenchman, Eyre Peninsula. × 30 diameters. Chloritoid partly enveloping andalusite. Chloritoid enclosures are quartz and rutile (dark). Tourmaline below.

PLATE XIII.

FIG. 1.—Chloritoid slate, Church Quarry, Tintagel. × 30 diameters. Sliced parallel to the cleavage. The diverse orientations of the chloritoid plates is indicated in the crystal sections. Intergrowths with muscovite are common. The dark areas are plates of ilmenite.

FIG. 2.—Chlorite chloritoid phyllite, Delabole-Trebarwith Road. × 30 diameters. The prominent crystals showing an hour-glass structure and set across the foliation are chlorite. The rod-like sections intergrown with muscovite are chloritoid. The base is largely a felted mass of sericite in which unoriented muscovite plates may be distinguished.

On a Meandrine Form of *Chaetetes.*

By LOUIS B. SMYTH, M.A., Sc.D., Lecturer in Palaeontology in the University of Dublin.

(PLATES XIV AND XV.)

THE fossil which forms the subject of this note was thought, when first found by me, to be a new genus of Tabulate corals. Since it may puzzle, and indeed has puzzled, others in a similar manner, it will perhaps prove useful to describe it.

ACKNOWLEDGMENTS.

Before proceeding with the description it is my pleasing duty to acknowledge the help received from Dr. Stanley Smith, who drew my attention to Thomson's species, *Chaetetes* (*Alveolites*) *Etheridgii*, as supplying the key to the affinities of the present form. I am also indebted to Dr. W. D. Lang for giving me every assistance in studying the specimens under his charge, and to Miss E. Goodyear, B.Sc., for the loan of specimens.

LOCALITY.

The fossil to be described was collected from the Carboniferous Limestone of the Great Orme's Head, Llandudno, in a small abandoned quarry 680 feet east of the semaphore, 1,200 feet south-east of the lighthouse, and 486 feet above O.D. Only a single example was found.

DESCRIPTION.

It is a globular mass 7 cm. in diameter. The original outer surface is not exposed. On the fractured and weathered surfaces radial elements can be seen with the naked eye curving outwards from the base in the manner of a massive coral. With a lens much finer concentric elements become visible crossing these, and giving the impression of a coarse Actinostroma. Where the radial elements are fractured transversely they are revealed as convoluted laminae.

A thin transverse slice (Pl. XIV, Figs. 1*a* and 1*c*) shows the radially folded, often branched, laminae forming a maze-like pattern. They have an average fairly uniform thickness of 0·34 mm. throughout the greater part of the specimen, and enclose meandrine spaces of about 0·30 mm. in width. The laminae appear pale brown by transmitted light, and the spaces are filled with a mosaic of clear, colourless calcite.

The structure of the laminae is indistinct, but can be seen to be fibrous at right angles to their surfaces. Many of them show a central zone up to about 0·1 mm. wide, which is generally brighter, but may be darker, than the borders, or merely marked off from the latter by indistinct dark lines.

There is no indication of stereoplasmic layers parallel to the surfaces of the laminae. Mural pores were not observed.

No regularity could be detected in the disposition of the laminae in transverse section, but they frequently form horseshoe-like curves, partially enclosing more or less rounded spaces.

A longitudinal section (Pl. XIV, Fig. 1*b*; Pl. XV, Fig. 1*b*) shows the laminae running in straight or gently curved, parallel or slightly diverging lines. The spaces between them are crossed at intervals by platforms suggesting tabulae. These tabulae are thin, 0·03 mm., very uniform in thickness, generally simple, but occasionally " splitting " once, flat or slightly curved. One tabula can often be traced for a considerable distance across a number of what, in the longitudinal section, appear to be separate spaces (in reality there is only one continuous space).

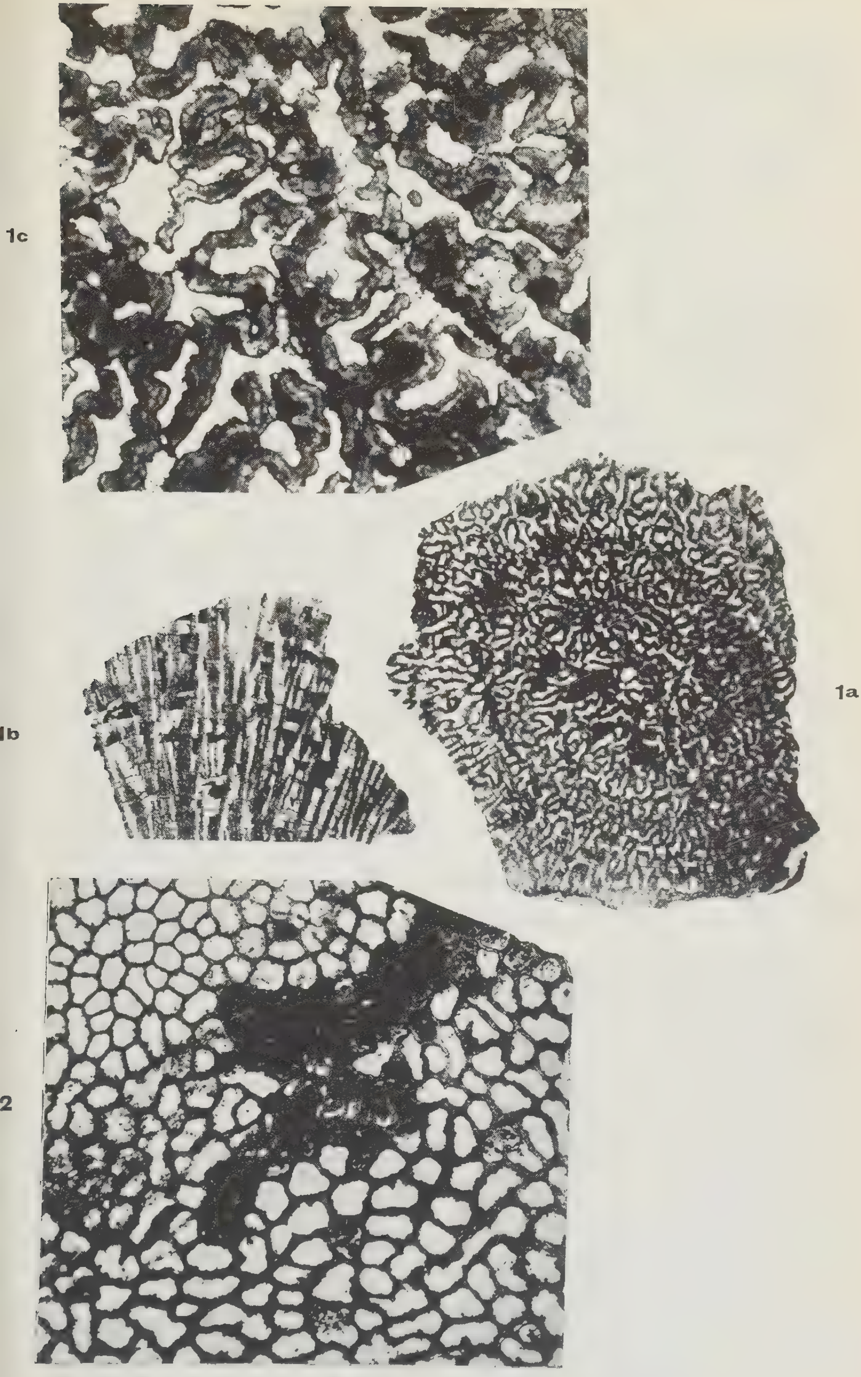
There are no septal ridges, and it is doubtful if any prominences occur which could be considered as septal spines.

Near the periphery of the specimen on one side is a discontinuity in the structure, separating off an outer zone from the rest. The break may have been due to destruction of a part of the organism, caused by injury or unfavourable conditions, and the subsequent spreading over this part of the neighbouring uninjured tissues. Apart from this there is no concentric zonal structure. The structure of this outer zone is for the most part similar to that of the rest, but on a rather smaller scale. At one spot, however, the laminae anastomose forming a few irregular enclosed spaces (Pl. XV, Fig. 1).

DISCUSSION.

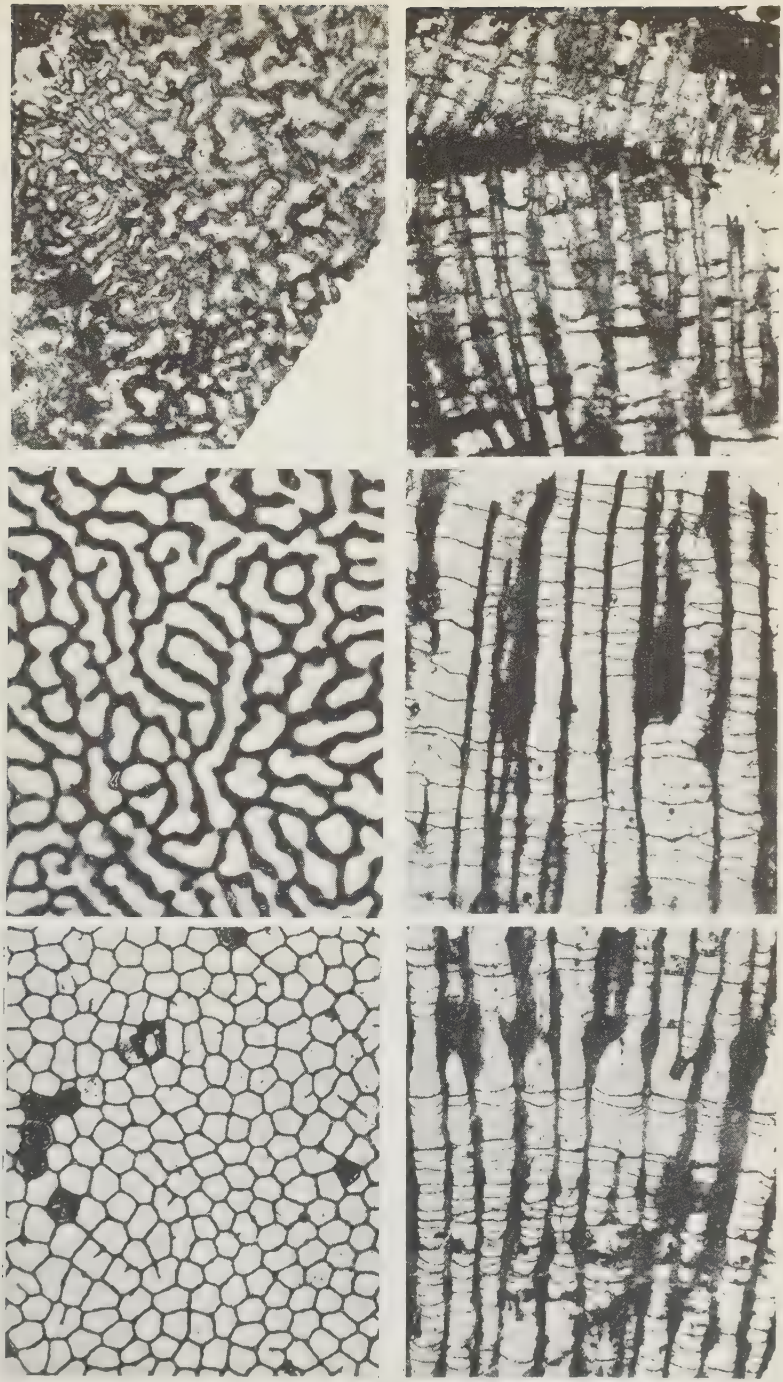
This curious fossil appears to be a meandrine modification of some species of Chaetetes. Pl. XV, Fig. 3 shows in transverse section a specimen of the normal condition of *Chaetetes septosus* (Fleming) from an horizon about 500 feet lower in the sequence at Great Orme's Head. Anything less like the fossil just described can scarcely be imagined. The walls are thin and the corallites polygonal. Some of the larger corallites have inward projections from their walls, which have been interpreted as incomplete

PLATE XIV.



NORMAL AND MEANDRINE FORMS OF *CHAETETES*.

[*To face p.* 32.]



NORMAL AND MEANDRINE FORMS OF *CHAETETES*.

partitions formed in the process of fission.[1] This character is well seen in the figure. The first indication of fission is a slight thickening of the wall. All stages may be traced from this up to the completed partition. If followed distally an incomplete partition wall would merge into a complete one.

Some specimens of *Chaetetes septosus* exhibit thickening of the corallite walls in places (Pl. XIV, Fig. 2). This phenomenon is frequent in the genus. In a specimen of *Ch. depressus* (Fleming), from the same bed as our meandrine form, the thickening occurs periodically in concentric zones, and septal ridges are developed only in these thickened regions.

Another phenomenon which may be observed in some specimens, otherwise resembling *Ch. septosus*, is the transverse elongation of the corallites, probably owing to incomplete fission of the polyps. It is associated with irregularity of the corallites and thickening of the walls (compare the upper and lower parts of Pl. XIV, Fig. 2). Nodular thickenings may be seen in some of the walls in the lower right-hand half of this figure. These may probably be regarded as incipient partition walls.

Specimens are met with in which the omission of partition walls has become an important feature, either in a particular region of the corallum, or throughout. Pl. XV, Fig. 2*a* illustrates this condition. Partial partitions are numerous, complete ones are often separated from one another by considerable intervals, so that the corallites, as seen in transverse section, are mostly elongated and sinuous. The walls often appear moniliform owing to the node-like swellings referred to above, due to rudiments of partitions. Here, it may be noted, the walls are all thick. To a form showing this tendency Thomson gave the specific name *Etheridgii.*[2] His figures show that the form he described only exhibited the elongated corallites in certain regions, and elsewhere possessed the normal structure of *Ch. septosus.* The specimen, on the other hand, from which the slice here figured (Pl. XV, Fig. 2*a*) was made, is uniform throughout, normal structure not being observed in any part of it.

It will be easily seen that, if this tendency to incomplete fission be pushed to extremes, a structure such as that described in the beginning of this paper would be arrived at, where there is only a single visceral chamber in the corallum. A tendency to thickening of the walls seems to accompany the meandrine tendency: the thickness of the walls in our fossil is extreme.

The section in the outer zone of the Llandudno meandrine (Pl. XV, Fig. 1*a*) helps to connect up the specimen with the more extreme variations of *Ch. septosus.* The part figured is the only spot where I could detect any approach to normal corallites.

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[1] Vide e.g. H. A. Nicholson, *On the Structure and Affinities of the Tabulate Corals of the Palaeozoic Period*, London, 1879, p. 260; J. Thomson, "On the genus *Alveolites* . . .": *Proc. Phil. Soc. Glasgow*, vol. xiii, 1882, p. 205.

[2] Loc. cit., p. 208, and pl. i, figs. 6–6*d*.

That this fossil is closely related to *Chaetetes* seems to admit of no doubt. It appears possible that it may have to be placed under *Chaetetes septosus* (Fleming), but the material at present available would not justify this step.

The single specimen obtained was taken from a rather weathered exposure. It may have been somewhat altered. The very perfect preservation of the delicate tabulae, however, makes it likely that the radial laminae have not been seriously changed, e.g. in thickness. A portion of the specimen treated with hydrochloric acid was entirely dissolved. It has, therefore, not been silicified.

HORIZON.

The associated fauna includes :—

Productus striatus.[1]
Brachythyris ovalis (Phil.).
Dibunophyllum sp.
Lithostrotion irregulare.
,, *junceum.*
,, *Portlocki.*

At 150 feet below occurs :—

Aulophyllum fungites (Fleming), near *mut. pachyendothecum* (Thomson) S. Smith.

The *Dibunophyllum* agrees with a species figured by Vaughan from upper D of Visé.[2] This association indicates an horizon equivalent to the D_2 sub-zone of the South-West Province.

DISPOSAL.

A portion of the specimen will be deposited in the British Museum (Natural History), the remainder in the Geological Museum of Trinity College, Dublin.

EXPLANATION OF PLATES XIV AND XV.

FIG.

PLATE XIV.

1.—*Chaetetes* sp. Great Orme's Head. *a*, transverse section through whole specimen. × 1·8. *b*, portion of longitudinal section. × 1·8. *c*, portion of transverse section. × 8·2.

2.—*Chaetetes septosus* (Fleming), Carb. L'st., "Middle White" [D]. Bryn Gwyn, North of Caerwys (Morton Coll., Brit. Mus., R 4300). Transverse section. (For longitudinal section of this specimen see Pl. XV, Fig. 4.)

PLATE XV.

1.—*Chaetetes* sp. Great Orme's Head. The same specimen as Pl. XIV, Fig. 1. *a*, portion of transverse section through distal layer. × 8·2. *b*, portion of longitudinal section including part of distal layer at the top of the figure. × 8·2.

2.—*Chaetetes septosus* (Fleming), forma = *Ch. etheridgii* (Thomson), Carb. L'st., "Upper White" [D], Llanymynech (Morton Coll., Brit. Mus., R 4474). *a*, transverse section. × 8·2. *b*, longitudinal section. × 8·2.

3.—*Chaetetes septosus* (Fleming). Great Orme's Head, from a level about 500 feet lower than the meandrine specimen, Fig. 1, of both plates. Transverse section. × 8·2.

4.—*Chaetetes septosus* (Fleming). The same specimen as Pl. XIV, Fig. 2. Longitudinal section. × 8·2.

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[1] See pl. xxxiv, fig. 3, in T. Davidson, *British Fossil Brachiopoda*, vol. ii, 1858–63.

[2] A. Vaughan, *Q.J.G.S.*, vol. lxxi, 1915, p. 41, pl. v, fig. 5.

REVIEWS.

THE GEOLOGY OF THE COUNTRY AROUND FLINT, HAWARDEN, AND CAERGWRLE (Sheet 108). By C. B. WEDD, W. B. R. KING, and others. Mem. Geol. Survey, 1924. H.M.S.O. Price 6*s.* 6*d.*

THE outstanding feature of this memoir is the detailed account of the Flintshire Coalfield. The northernmost corner of that basin has already been described in the memoir on the sheet to the north (96, Liverpool), and the account of the southern continuation on the Llangollen Sheet is still awaited with much interest. The coalfield has long been known as one exceptionally difficult to work on account of the complex tectonics, especially faulting, and the variations in the deposits. Therefore the information here collected and collated will be of great use and value to those concerned with the coal industry, for the work has been efficiently carried out.

A chapter on the tectonics of the whole area, by Mr. Wedd, forms a fitting introduction to the memoir. This chapter is the first detailed exposition of the views that he has frequently but too briefly expressed, namely, of the clockwise " spiral " movements (a term which has given rise to some misconception) of the Carboniferous rocks around the Silurian block that forms the Denbighshire Moors and the Clwydian Range. These views, as now expounded, carry more conviction than the summarized statements hitherto available. There is little doubt that the idea of these " spiral " movements throws much light on the structural features of the arcuate basin of the coalfield and the anticlines within it. But why should the short two-paged chapter on the Silurian rocks follow that on Tectonics ? As the authors were aware, the post-Carboniferous movements were controlled by the Silurian massif, for the later rocks were bent round it ; an account of the structural features of this massif, therefore, would have given point to the discussion of the tectonics. If a question of policy demanded that only the Upper Carboniferous rocks should be revised, such a decision would appear to be very short-sighted. The dominating influence on later movements of the rock-types and structures in more ancient rocks adjoining coalfield areas has too often been indicated to need further emphasis. In the area here considered, it is peculiarly unfortunate that the chapter on Silurian rocks shows little or no advance in knowledge since 1866. Sir Andrew Ramsay said little about the Clwydian Range and adjoining part of the Denbighshire Moors ; the use of graptolites, essential to the elucidation of the area, was not vouchsafed to him. He referred the rocks to the Wenlock, and Sir Aubrey Strahan, in his revision of the area in 1879–81, was compelled to confine his attention largely to post-Silurian rocks. It is true that some lithological variations were mapped, but no account of the graptolitic succession was attempted. This was not surprising in view of the poor state of preservation of the fossils, the cleavage of the beds and the absence of knowledge of a standard

British succession. In the present century, however, after the lead given by McKenny Hughes[1] in the district, it might be expected that rocks comprising one-sixth of the area of Sheet 108 would be referred to their proper horizon. The present authors deserve sympathy, for they are obviously aware that (with one doubtful exception of a graptolite picked up on the slopes of Moel Fammau) the fossils collected by themselves and others reveal a succession of the graptolitic zones of the Ludlow, and of the Ludlow only, while at the same time they have to bring that knowledge into accord with the earlier references of the rocks to the Wenlock. The result in chapter iii of the Memoir is naturally sad. Moreover, though this is a minor point, something seems to have gone wrong with the records of graptolites found 440 yards N.E. of Pool Park, where *M. leintwardinensis* is recorded, together with species characteristic of lower beds, as from a quarry which displays beds closely resembling the "slab-horizon" of Dr. L. J. Wills in the Llangollen area. It might have been as well, too, not to cite *Orthis calligramma* from beds referred elsewhere by McKenny Hughes to the Ludlow.

It is to be hoped that when the map and memoir of the Llangollen area are published, the Silurian rocks will receive adequate treatment in view of the good work that has already been accomplished there. But how such an account will be linked up with that of the continuation of the rocks in Sheet 108 is not easy to see.

As in the case of the Silurian, the Carboniferous Limestone and "Millstone Grit" were not re-surveyed. This also is to be deplored, for the solution of the vexed problem of the true relations of the Chert Beds, Cefn-y-fedw Sandstone, Holywell Shale, Gwespyr Sandstone, and Lower Coal Measures proper would undoubtedly have been forthcoming, now that the goniatites are being more thoroughly investigated.

The Trias, Glacial, post-Glacial, and Recent deposits are considered fully in the later chapters. The memoir, as a whole, is an excellent production and the small amount of space here devoted to its praise is no measure of the quality and quantity of the information it provides. But the policy of leaving the older rocks unrevised certainly calls for vigorous protest.

P. G. H. B.

INTRODUCTORY GEOLOGY. By L. V. PIRSSON and C. SCHUCHERT. pp. x + 693, with a coloured map and 395 figures. New York: John Wiley & Sons, Inc.; London: Chapman & Hall, Ltd., 1924.

THE large textbook in two volumes by the late Professor L. V. Pirsson and Professor Charles Schuchert is by this time well known and has taken its place as a standard work. The present book is essentially a one volume edition of it, the first part, by Professor Pirsson, being simply reprinted, except that Chapter XVI, on Ore Deposits, has been rewritten by Professor A. M. Bateman, occupying exactly the same number of pages. The second volume, however, by Professor Schuchert, has been very greatly condensed, containing now only about 210 pages.

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[1] See also the account of zones and fossiliferous localities in the Lower Ludlow by F. H. Edmunds, *Proc. Liverpool Geol. Soc.*, vol. xiii, p. 335, 1923.

This book in its present form will be found extremely useful by non-American geologists, and especially in this country. The foundation of British physical geology is the doctrine of uniformitarianism, which is doubtless fundamentally true, but here the conditions, climatic and other, are such that processes are perhaps unusually slow, and the doctrine of uniformitarianism has been pushed to extreme limits. In other countries on a larger scale and with more violent climates things progress faster, and it is very good for English students at some stage of their career to read a textbook written from the American point of view. The present volume is admirably adapted for this purpose.

THE GEOLOGY OF PARTS OF THE PERSIAN PROVINCES OF FARS, KIRMAN AND LARISTAN. By GUY E. PILGRIM, D.Sc., F.G.S. Mem. Geol. Survey India, vol. xlviii, pt. 2, 1924. pp. 1 to 116, 6 pls., 10 figs.

THE SULPHUR DEPOSITS OF SOUTHERN PERSIA. By GUY E. PILGRIM, D.Sc., F.G.S. Rec. Geol. Survey India, vol. liii, pt. 4, 1922. pp. 343–58, 2 plates.

THESE publications are a valuable addition to our knowledge of the stratigraphical geology of Persia, and incorporate the results of a geological reconnaissance undertaken by the author in 1917–18. In the areas examined the geological formations are generally the same as those described by Dr. Pilgrim in the Persian Gulf and adjoining parts of Persia and Arabia (*Mem. Geol. Surv. Ind.*, vol. xxxiv, pt. 4, 1908). The memoir is well illustrated with two geological maps and ten diagrammatic cross-sections showing complex structure and intense folding. Considerable fresh light is thrown on the age and stratigraphical relations of the different formations, as well as on the origin of the gypsum, salt, and sulphur deposits contained in them. The palaeontological identifications are mostly provisional.

The classification of the Hormuz Series has been revised, the age proposed for these beds being pre-Cretaceous, probably Triassic and Jurassic. The thick beds of salt at the base of the series are thought to have been formed in land-locked gulfs and lagoons, and at the top of the group a widespread unconformity has been identified. The Hormuz rocks are more strongly folded than the overlying Hippuritic Limestone, in which formation where gypsum occurs it is explained as an alteration product of the limestone. The Eocene rocks are treated very briefly, it being mentioned that the

Nummulitic Limestone forms great anticlinal ranges, which the author never climbed or penetrated. The Khamir, Fars, and Bakhtiyari Series are very similar to the representatives of these formations in other parts of Persia.

As to the sulphur deposits, it is suggested that they are due to the emanation of sulphurous vapours from a deep-seated source, it being noted that the more important deposits occur in connexion with faults. Their age is probably Pleistocene or subrecent.

W. L. F. N.

THE GEOLOGY OF THE EASTERN RAILWAY. SECTION I. PORT HARCOURT TO ENUGU. By R. C. WILSON, notes by A. D. N. BAIN. Geol. Survey of Nigeria. Bull. No. 8, 1925, pp. 95, pls. i–vii. Geol. map col. 1 : 250,000, outline map and hydrographical map.

THE ground covered by this Report is not altogether new to students of Nigerian Geology, for Mr. Bullen Newton has described the Mollusca of Ameki in the third *Bulletin*, and Mr. Bain the Coal-fields of Enugu in the sixth.

Nevertheless much additional work has been done, and the history of late Mesozoic and Tertiary times are here set forth with more claim to completeness than has hitherto been possible. Considerable emphasis is placed on the movements which occurred at the close of the Mesozoic, the approximate date being now fixed for the first time between the deposition of the Post-Turonian Coal Measures and the overlying Sandstones, which closed the Cretaceous, and the deposition of a Carbonaceous and Pebbly Sandstone, Pre-Middle Eocene in age, the earliest of the Tertiaries. These beds show a repetition of the lacustrine and swamp conditions under which the earlier Coal Measures were laid down. The formation of coal seams again took place, and of these, which do not strictly come within the area of the map, a general account, with analyses, is given. They are nearer to the Enugu coals than to the later lignites. The carbonaceous shale facies is more prominent in the lower part of the group, the pebbly sandstone in the upper.

An interesting section is devoted to the physiography of the country and its causes. Captain Wilson considers that before the deposition of the Tertiary beds, a river, called by Kitson the Older Benue, flowed from the north, occupied what is now the valley of the Ewayon, and continued south along the valley of the Cross River. The last is an important stream which to-day sweeps from the east in a roughly elliptical course round the Oban Hills, once a high headland of Archaean rocks in a Cretaceous sea, receiving the Ewayon from the north at a point where its valley takes a marked bend from N.W. to S.W. The formation of the prominent escarpment, which stretches south from Enugu for some 45 miles, is attributed to this Pre-Middle Eocene drainage. The lacustrine conditions of the period of the Pebbly Sandstone submerged much of this ancient valley, but on renewed elevation the northern part of the Older Benue was diverted westwards to join a Central River, considered by Kitson as the ancestor of the Niger, flowing to the west of the Enugu escarpment. Not merely this, but a northerly directed drainage from the region of the Upper Cross River was initiated, whereby that river itself was forced to flow N.W.—at the bend already mentioned—to join the now westerly trending Benue. At this time the southern part of the escarpment was formed. This elevation and subsequent denudation preceded the marine invasion which carried with it the rich Upper Lutetian fauna of the Bende-Ameki Group, deposition continuing with a possible unconformity until the succeeding unfossiliferous Lignite Group was complete.

The wide distribution of lignite is of importance second only to the importance of the coal.

The Ijebu beds are apparently absent, and the latest scene of the history was the submergence which allowed of the deposition of the widely spread Benin Sands in the lagoons of late Pliocene or Pleistocene time, and the ensuing elevation which gave rise "to a complete reversal of the whole of the northerly flowing. drainage" into the Benue and the establishment of the present Cross River system.

Full details are given of the various groups, the general appearance of the beds being shown in a series of those admirable photographs to which we are accustomed from the Nigerian Survey. The Geological Map (in colours) is contoured at 100 feet intervals. Altogether nothing but praise can be given to this description of a country where, it may be remembered, twenty years ago no white man's life was safe without an adequate escort.

J. P.

INTERIM REPORT ON THE GEOLOGY OF THE COUNTRY SOUTH OF UMSWESWE, HARTLEY DISTRICT. By A. M. MACGREGOR. Southern Rhodesia Geological Survey. Short Report No. 16. Issued 1st August, 1924. pp. 1–18. Geological Sketch Map.

THE area included in this Report is the southward continuation of that described in Bulletins Nos. 1 and 5, by the late Mr. Zealley and Mr. Lightfoot respectively. The railway from Bulawayo to Salisbury divides it into two parts, nearly of the same size. The map, which covers an area of about 100 square miles, shows three subdivisions of the "Basement Schists", of which the "Siliceous Schists, mainly sedimentary", and the underlying "Greenstone Schists" form roughly equal proportions, either including a few strips of the third member, the "Banded Ironstone", a term including different rocks, geographically separate. Flanking masses of granite and syenite occupy about one-third of the area. Three types of the "Siliceous Schists" are recognized: (*a*) predominating and indisputable conglomerates, with interbedded greywackes, some possibly belonging to a series later than the older schists;

(*b*) fine-grained slaty rocks, and (*c*) a sericitic quartz-schist of " very doubtful origin ". The whole are continuous with the rocks described by Zealley from the neighbourhood of Gatooma, his " porphyry, felsite, and ultra-acid rocks ". When uncleaved, the sedimentary nature of the conglomerates and greywackes is clear, otherwise they are indistinguishable from acid rocks originally of igneous origin. The eastern granite shows feeble foliation and contains microcline and orthoclase in nearly equal proportions ; the western consists of a grey granite containing albite, supposed to be of secondary origin, and another mass with porphyritic microcline in addition to albite in the base. Six pages are devoted to the economics of the area, with brief but valuable descriptions of the mines.

J. P.

LES LACS : LEUR MODE DE FORMATION—LEURS EAUX—LEUR DESTIN. By Professor L. W. COLLET, of Geneva, late Director of the Service de l'Hydrographie Nationale Suisse. Librairie Octave Doin, Paris, 1925. 320 pp. with index, 63 figures, 28 plates. Price 35 francs (French).

PROFESSOR COLLET has followed his book on *Les Dépôts marins* with the present volume entitled *Les Lacs*. Although originally intended for the same *Encyclopédie scientifique*, it has been issued in a larger form to do justice to its many interesting and beautiful illustrations. The work will appeal to several types of readers : to geologists who like to think of origins ; to physicists interested in colours and temperatures ; to industrialists with an eye to the exploitation of water power ; and to the educated public who will readily appreciate that lakes present many problems of their own.

Most of the subject matter is supplied by Switzerland, but this is no disadvantage to the non-Swiss reader. He feels that he is learning from a well qualified guide the wisdom that has accumulated regarding the best known lakes of the world ; and he finds that the generality of the title, while providing an escape from local detail, has freely admitted contributions from every quarter of the globe. In some cases, the extra-Swiss material is introduced by way of comparison. For instance, an account of the Märjelen Lake, dammed by the Aletsch Glacier, is followed by references to vanished glacier lakes of America, Britain, and Sweden. In other cases the outer world is given priority, as where the solution lakes of the neighbourhood of Trieste, or the sediments of the Scottish freshwater lochs, are selected as typical of their kind. Finally, there are whole categories of lakes—such as crater lakes, salt lakes, and the lakes of the Rift Valley in Africa—that have no counterpart in Switzerland, but are accorded their proper space in the present volume.

The treatment of the subject does not stop at the shores of the lakes : many of the rock basins of Switzerland and elsewhere are ascribed to glacial erosion, and are correlated by the author with characteristic features of the adjacent landscape. The seasonal fluctuations of lakes are traced to the fall of rain or the melting of snow; and the regularization of torrents by afforestation is discussed in detail. The growth of sub-lacustrine deltas is measured and brought into relation with the transport of sediments by rivers. The underground discharge of solution lakes is tracked to distant springs by the use of dyes.

Attention is also given to the lakes of the past, responsible for the freshwater *molasse* of Switzerland and the *limagne* of France; and good advice is offered to engineers whose dams are to make many of the lakes of the future. In this last connexion it may be said that much of the value of the book depends upon its practical bearing. The emphasis laid on numerical data in regard to water supply, sedimentation, etc., is a modern feature that will be much appreciated. A useful bibliography is supplied at the close of every chapter.

E. B. BAILEY.

HANDBOOK OF THE GEOLOGY OF IRELAND. By the late Professor G. A. J. COLE, D.Sc., F.R.S., M.R.I.A., and T. HALLISSY, B.A., M.R.I.A. pp. 1–82, figs. 1–7, and maps. Published by T. Murby & Co., 1924. Price 8*s*. 6*d*.

AS stated in the preface this book is based on the late Professor Cole's contributions to the *Handbook of Regional Geology*, with the name of Mr. Hallissy added as joint author. The book as now issued contains little new matter, though here and there the subject is brought up to date by the insertion of a fresh paragraph; there is, however, a great improvement in arrangement which will enhance its value to the student. All the sections relating to geological history are now collected into a chapter by themselves and read as a continuous whole; and the sections dealing with economics and orographic elements are similarly treated, with equal gain to the reader.

G. L. E.

ON INTRAFORMATIONAL FOLDING CONNECTED WITH THE GLACIAL BED IN THE TABLE MOUNTAIN SANDSTONE. By S. H. HAUGHTON, L. J. KRIGE, and A. V. KRIGE. Trans. Geol. Soc. S. Africa, vol. xxviii, 1925, pp. 19–25, with 3 plates.

THE phenomenon generally known as intraformational folding has attracted a good deal of attention in various instances, and is susceptible of explanation in several different ways. In the instance here described there seems to be no doubt that it is to be attributed to the passage of a contemporaneous ice-sheet.

It has long been known that the Table Mountain Sandstone includes a bed containing obviously glaciated boulders; such are to be found on the summit of the mountain itself. The authors of this paper have discovered that in two localities, the Wellington Sneeuwkop and the Somerset Sneeuwkop, tillites are associated with a zone of sharply folded strata, intercalated between strata with a gentle uniform dip. The folded zone has a total thickness of about 300 feet, consisting of sharp anticlines, sometimes overfolded, with broader synclines between; here and there the tops of the anticlines are sheared off, and the synclines are more or less completely filled up by tillite, which in many respects resembles the Dwyka conglomerate. Since the age of the Table Mountain Sandstone is certainly either Lower Devonian or Silurian, probably the former, the occurrence of an ice-age in the Southern Hemisphere is thus accurately dated. The paper is illustrated by some striking photographs.

R. H. R.

ON PLATINUM-BEARING HORTONOLITE-DUNITE OF THE LYDENBURG DISTRICT. By P. A. WAGNER and E. T. MELLOR. Trans. Geol. Soc. S. Africa, vol. xxviii, 1925, pp. 1–17, with 2 plates.

RATHER more than a year ago we reviewed in these columns an account of the discovery of important quantities of platinum in quartz veins in the Waterberg district. The present publication chronicles another notable find of the same metal, but this time in more orthodox surroundings, namely, in ultrabasic and basic rocks belonging to the norite zone of the Bushveld igneous complex, and in eluvial and alluvial deposits derived from their disintegration. Discoveries have been reported from a strip of country, nearly 60 miles in length, on either side of the Steelpoort River in the Sekukuniland and Dwars River areas of the Transvaal.

The lower part of the great three-miles-thick sheet of norite shows wonderful differentiation, including much chromite-rock which is of great commercial value. Platinum-bearing rocks have been found at two horizons in this part of the sheet associated with the chromitites. The particular rock concerned is a dunite, occurring in streaks and lenses, mainly composed of a peculiar iron-rich olivine, here called hortonolite, ($nFe_2SiO_4 + Mg_2SiO_4$, where n varies from 1 to 2).

The rock is obviously an extreme product of normal differentiation, and experience shows that varieties richest in iron-olivine contain most platinum, which ranges up to 33 dwt. per short ton in the Onverwacht rock, while the Mooihoek rock probably averages 4 dwt. throughout. At present prices these amounts should pay well, and the discovery has given rise to a considerable boom in South Africa.

R. H. R.

THE GEOLOGY OF THE COUNTRY AROUND WEM. By R. W. POCOCK and D. A. WRAY. Mem. Geol. Survey, Expl. Sheet 138. pp. vi + 118, with 5 plates and 2 text-figures. 1925. Price 3*s*. net.

THIS memoir deals with a rather uninteresting district, of low relief and largely covered by drift and alluvium, so that exposures are for the most part few and poor. The Longmyndian rocks of Haughmond just come into the southern margin of the map, and there are small patches of Keele and Enville beds. Otherwise it is mainly Trias, considerably faulted and difficult to make out. In places copper ores are found in the Trias. The Rhaetic and Liassic outlier of Prees, N.E. of Wem, is perhaps the most notable feature, but this is not well exposed. At Acton Reynald a dolerite dyke, presumably Tertiary, cuts the Trias: it is very much decomposed, but may have been a tholeiite, according to Dr. Flett, who has studied microscopic sections of it. The Glacial deposits forming part of the drifts of the Cheshire and North Shropshire area comprise material from many sources, brought by two main ice-streams from the Irish sea and from Wales respectively. In the later phases an extensive lake was formed over much of the area at about 300 ft. O.D.

CONTOUR PLAN OF THE TRENCHERBONE SEAM AND ASHTON BLACK MINE, SOUTH LANCASHIRE COALFIELD (with explanatory pamphlet). By G. HICKLING, D.SC., F.G.S. Scale 2 inches to 1 mile. Size of map about 5 ft. 6 in. × 2 ft. 6 in. Published by the Lancashire and Cheshire Coal Association, 1924.

THIS well-printed coloured map of a portion of the South Lancashire coalfield is reduced from five large plans on the scale of 6 inches to a mile, privately circulated to members of the Lancashire and Cheshire Coal Association. We are informed that it will be supplemented in due course by a memoir and by sheets of sections. The contour-lines and the colours show the depths of one particular seam only, and therefore give in a graphic form a picture of the general structure of the area.

The map is printed in fourteen colours on the layer system, and shows contours ranging from + 1,500 to − 5,500 feet O.D., nearly all founded on actual observation, there being very little hypothetical extension beyond proved areas. The town of St. Helens is in the extreme S.W. corner, Bolton near the middle of the northern side, and Hyde in the S.E. corner. As is well known this is a highly faulted area, and the faults are very well brought out.

This map is an admirable example of the use of underground contours, a method of representation which is so useful in nearly all forms of investigation of concealed structures, and it should be studied carefully by all geologists whether interested in the theoretical or the applied branches of their subject.

USEFUL ASPECTS OF GEOLOGY. By S. J. SHAND. pp. x + 197, with 23 text-figures. London: T. Murby & Co., 1925. Price 7*s.* 6*d.*

IN this small book Professor Shand has presented a brief introduction to the general principles of geology, with a leaning towards the practical applications of the subject, such as should be very useful to absolute beginners. The author's experience as a teacher in a South African university has naturally given him an insight into the special needs of such students, as in that country everybody is, or wants to be, more or less of a geologist, a state of affairs particularly stimulating to one accustomed to the attitude of boredom commonly encountered in places where geology is less of a living force and more of an academic study.

The text, though necessarily brief, appears to be well adapted to the object in view, and the short bibliographies attached to each chapter are a useful feature: they might perhaps have been slightly extended with advantage. A few of the books recommended are not quite up to date. The figures, which are not numerous, appear to be new and not a mere repetition of worn-out blocks, as is too often the case in geological books, and the author has wisely avoided reproduction of photographs of scenery, which usually show nothing at all. The book may be regarded as very useful as a practical and not verbose introduction to applied geology.

FRENCH-ENGLISH AND ENGLISH-FRENCH DICTIONARY OF TECHNICAL TERMS AND PHRASES USED IN CIVIL, MECHANICAL, ELECTRICAL, AND MINING ENGINEERING, AND ALLIED SCIENCES AND INDUSTRIES. By J. A. KETTRIDGE. pp. i–xvi + 1137. London: George Routledge & Sons, Ltd., n.d. (1925). Price £2 10*s.* net.

THIS work should prove of considerable use to geologists since it includes all the ordinary terms of physical geology, petrology, mineralogy, and mining, with a small number of stratigraphical terms. It also gives tables of abbreviations and symbols in common use, conventional signs, conversion factors, weights and measures, as well as a telegraphic code by means of which any entry in the dictionary can be coded in one cipher word of ten letters. The book is very clearly printed, but is necessarily of considerable weight.

A BIBLIOGRAPHIC LIST OF PRE-STORMBERG KARROO REPTILIA. By S. H. HAUGHTON. Trans. Roy. Soc. S. Africa, vol. xii, pp. 51–104.

AS the title indicates this paper is purely bibliographic. It contains references to the chief literature dealing with each of the species of pre-Stormberg Karroo reptilia. As it runs to over 50 pages, this fact alone gives some idea of the number of species now known and the bulk of the literature referring to this group of the Vertebrata, which are of such interest from many points of view. It cannot fail to be of great value to all workers on vertebrate palaeontology.

ANNUAL REPORT OF THE COUNCIL OF THE YORKSHIRE PHILOSOPHICAL SOCIETY FOR THE YEAR 1924.

BESIDES the matter usually contained in a publication of this kind referring to the local activities of the Society, which includes some useful meteorological observations, this report contains an interesting article, written by Mr. W. E. Collinge, on the occasion of the centenary of the appointment of John Phillips as the first Keeper of the Yorkshire Museum, with an excellent reproduction of a portrait now in the Museum at York. It is unnecessary to enlarge at length on John Phillips as the nephew of and assistant to William Smith, and as himself one of the commanding figures in the heroic age of British geology : his varied career was crowned by his long tenure of the chair of geology at Oxford in succession to Buckland. His great works on the geology of the mountains and sea-coast of Yorkshire will always be classics in the science. It is hoped that a much-needed enlargement or rebuilding of the Yorkshire Museum may eventually prove a fitting memorial of one who, though not a native of the county, added much to its share in the development of geology.

REPORTS AND PROCEEDINGS.

MINERALOGICAL SOCIETY.

17th March, 1925.

A Demonstration on quartz twinning, illustrated by models, was given by Sir William Bragg.

"The Structure of Aragonite." By S. Tomkeieff.

A new method of etched figures which can be used for the estimation of crystal structure is described. A structure of aragonite, constructed in such a way that the transformation into calcite can be attained with a small expenditure of energy, was tested by this method, and gave perfect agreement. For six of the eight faces examined, the spacings were the same as those observed by Sir William Bragg, but the remaining two gave only half of the spacings observed. This anomaly was explained by the hypothesis that aragonite in its natural occurrence has undergone a partial transformation into calcite. The structure proposed is unable to explain the intensities of X-ray spectra. Aragonite is considered to be pseudo-orthorhombic. Experiments made on the precipitation of $CaCO_3$ in a colloidal state throw some light on the genesis of aragonite and its relation to calcite.

"Crystalline structure of Pentaerythritol Tetranitrate." By Dr. I. E. Knaggs.

The X-ray examination showed that the dimensions of the ditetragonal bipyramidal unit cell are a=b=13·2Å, c=6·66Å, and that it contains four molecules, each possessing four-fold symmetry. The crystals are built on the Bravais lattice Γt and belong to the space-group D_4h^7. A structure was proposed in which the molecules have a diagonal axis with two planes of symmetry parallel to (100) intersecting in it. There is a considerable departure from the tetrahedral angle of the bonds from the central carbon atom of the molecules. The strain caused thereby together with the comparative proximity of eight oxygen atoms at intervals in the structure were thought to be contributory causes of the explosive nature of the compound. The configuration of the nitro-group ($-NO_2$) was discussed; the structure was in favour of the oxygen atoms being equivalent.

"Potash-oligoclase from Mt. Erebus, South Victoria Land, and Anorthoclase from Mt. Kenya, East Africa." By E. D. Mountain.

Felspar crystals of two types, occurring in the tuffs of Mt. Erebus, have a chemical composition intermediate between anorthoclase and andesine and are referred to potash-oligoclase, being identical with certain rhomb-porphyry phenocrysts. These are described and compared with similar crystals from Mt. Kenya and Kilima-njaro, which, however, contain less lime. A complete series of felspars is shown to exist between anorthoclase and andesine having continuously varying properties and mostly of porphyritic occurrence. This necessitates a slight modification in the definition of kenyte, but the limits of the type must depend upon the natural series, rather than upon any chemical distinction.

"Further Notes on the Association of Lime with other Oxides of RO-type in Minerals." By Dr. A. Brammall.

Volume-relationships accentuate the differences in chemical behaviour between lime on the one hand and magnesia, ferrous oxide, and manganese oxide on the other, and partly control those early molecular associations which promote differentiation in the fluid magma. Particular cases of differentiation in the Dartmoor granite furnish features analogous with those of the anorthosite-peridotite schism and suggest also that a high concentration of ferrous oxide and magnesia promotes the early separation of orthoclase as phenocrysts, and the zoning of the groundmass plagioclase.

"Crystallographic Data of some new Organic Compounds." By G. Greenwood.

Crystals of some twelve new substances recently prepared by various chemists were measured in the Crystallographic Laboratory of the University of Manchester, and the crystallographic constants and isomorphous relationships were determined.

YORKSHIRE GEOLOGICAL SOCIETY.

4th April, 1925.

"The Age of the Lower Carboniferous Beds immediately below the Millstone Grit of North-West Yorkshire." By L. J. Chubb and R. G. S. Hudson.

The main areas of Millstone Grit of North-West Yorkshire are those of Arkengarthdale Moor, Abbotside Common, and the area to the east of Coverdale and Wharfedale. Two marine horizons, the Colsterdale marine band and the Cayton Gill Beds, have been described from the latter area by Bisat and Hind. The same horizons are represented in the Abbotside Common area by the Hearne Gill Limestone and the "Trilobite Beds" of Shunner Fell, and are also found in the Arkengarthdale area. A continuity of horizon for the Millstone Grit of North-West Yorkshire is thus established.

The Lower Carboniferous beds immediately below the Millstone Grit vary greatly in horizon. The highest beds belong to the Fell Top Limestone Series and occur in the Arkengarthdale area. From here southwards, the Millstone Grit rests on progressively lower horizons until at Appletreewick Moor it rests on the horizon of the Hardraw Limestone or even lower, and the greater part of the Yoredale series is missing. Where exposed, the base of the Millstone Grit rests upon an eroded surface and there is no evidence of a passage from one formation to the other. It is, therefore, suggested that in North-West Yorkshire the Millstone Grit is unconformable on the Lower Carboniferous.

"The Millstone Grit and Yoredale Rocks of Nidderdale." By L. H. Tonks, M.Sc., of H.M. Geological Survey, Manchester.

The cutting of the trench for the dam of the new Scar House Reservoir in Upper Nidderdale provided a favourable opportunity for re-examination of some outstanding problems in the geology of the dale. Periodical visits have been paid to the trench section, and the natural exposures have been worked.

The lowest bed is exposed at Limley, where the *Orionastrea phillipsi* band at the base of the Middle Limestone has been recognized. The Middle Limestone, about 120 feet thick, in this dale is separated by shales from two thin limestones, which are considered to be the equivalents of the Five Yards Limestone of Wensleydale.

The lowest bed of the Millstone Grit is an attenuated representative of the Bearing or Grassington Grit of Wharfedale, and this grit rests unconformably on various horizons of the Five Yards Limestone. In the reservoir trench section this junction was clearly displayed. The eroding base of the grit was marked by the occurrence of a basal conglomerate, in which occur nodules, apparently phosphatic.

MANCHESTER GEOLOGICAL ASSOCIATION.

"The Succession below the Kinderscout Grit in North Derbyshire." By J. Wilfrid Jackson, M.Sc., F.G.S.

The paper contains the results of researches commenced before the war, and continued at intervals during recent years. A detailed account is given of the stratigraphical and palaeontological succession of the beds between the Kinderscout Grit and the Carboniferous Limestone, and special attention is devoted to the Shales with Limestones which overlie the massif. These Shales, called by the author the Edale Shales, have been referred in the past, first to the Yoredale Series and later to the Pendleside Group. Evidence is given to support the view expressed in an earlier paper that the shales in question are not related in any way to the strata just named, but are stratigraphically above them. The fossils are shown to be identical with those occurring in the Sabden Shales of Lancashire and their equivalents elsewhere, and the same succession of goniatite-zones is present. The correct determination of the fauna of the Edale Shales has had an important bearing upon the question of the age of certain beds ascribed to Kinderscout Grit in Lancashire and Yorkshire. The evidence derived from the type area of the Kinderscout Grit has rendered it necessary to discard the term Kinder Grit in the case of the grit overlying the Pendle Grit and underlying the Sabden Shales. On the other hand, it confirms the attribution of the name Kinder Grit to the grit overlying the shales in the Todmorden and Hebden Valleys.

CORRESPONDENCE.

CRETACEOUS AMMONITES.

SIR,—In part ii of the Monograph of the Ammonoidea of the Gault (Palaeontographical Society's volume for 1922) an ammonite (*Leymeriella* aff. *regularis*) figured on pl. viii, fig. 5, was stated to be from the "Shenley Limestone" (Lower Albian *regularis* zone). There is no doubt about the age of this ammonite, but Dr. Kitchin and Mr. Pringle have directed my attention to the fact that by this mode of statement I was conniving at the dating of those limestone lenticles as of *regularis* age. I should therefore be glad if you would give me space in the GEOLOGICAL MAGAZINE to express my regret at not having qualified the statement as to the age of the ammonite by the addition of "(? derived)", because the limestone lenticles are characterized by an assemblage of fossils (not cephalopods) which Dr. Kitchin, Mr. Pringle, and other palaeontologists consider unimpeachable evidence of a Lower Chalk age. Further, there is good reason to doubt whether the ammonite in question was actually found in one of the limestone lenticles, as pointed out some time ago by Dr. Kitchin and Mr. Pringle (GEOLOGICAL MAGAZINE, Vol. LVII, 1920, p. 102).

L. F. SPATH.